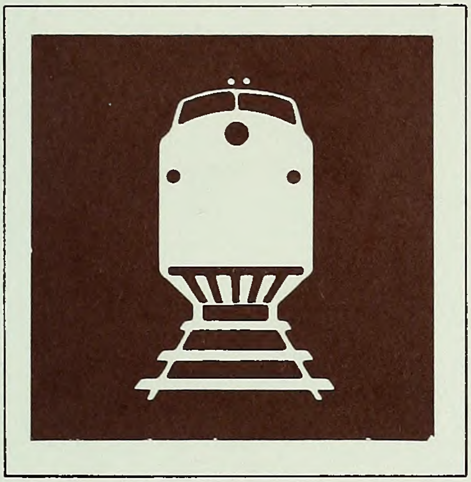
Oil and Gas Pipelines in Coastal North Carolina: Impacts and Routing Considerations



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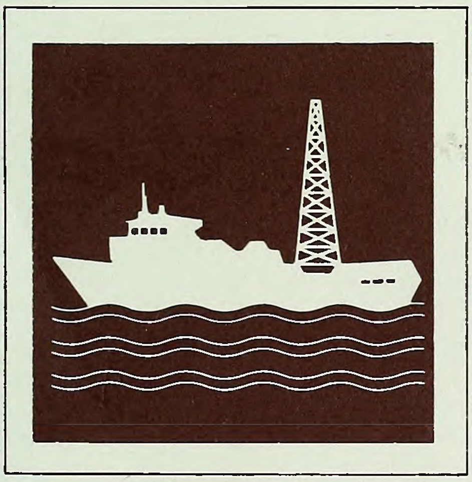

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North Carolina
Coastal Energy Impact Program
Office of Coastal Management
North Carolina Department of Natural Resources
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OIL AND GAS PIPELINES IN COASTAL NORTH CAROLINA:

IMPACTS AND ROUTING CONSIDERATIONS

by

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December 1982

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- the members of our two advisory committees (listed at the back of the report), who reviewed our drafts and provided us with numerous helpful suggestions and advice;

- the countless people in state agencies, universities and industry, both within North Carolina and in other states, who generously gave us their time and the benefits of their experience;

- Mr. James Smith, the North Carolina Coastal Energy Impact Program coordinator, for his helpful suggestions and constant support;

- the many people at both North Carolina State University and Science Applications, Inc., who, though their names do not appear on the cover page, contributed substantially to the completion of this report.

Note

Just when we thought we had all the complicated jurisdictional questions and agency acronyms figured out, Secretary of the Interior James Watt reorganized the Interior bureaucracy handling OCS oil and gas development. The result is the newly formed Minerals Management Service (MMS), which is responsible for exercising the following:

1) All functions carried out previously by the abolished Conservation Division of the U.S. Geological Survey;

2) Outer Continental Shelf Program support activities, including functions of the Office of OCS Program Coordination; all functions related to the management of offshore energy and minerals administered by the Bureau of Land Management; all functions that support the OCS program in the Geologic Division and the Office of the Assistant Director for Resource Programs of the U.S. Geological Survey; oil spill trajectory analysis functions of the Office of Earth Science Applications, U.S. Geological Survey; all functions of the Office of Policy Analysis relating to scheduling the sale of leases of OCS lands; and all functions relating to the OCS program transferred from the Department of Energy.

The report refers to the Minerals Management Service wherever current functions and responsibilities are discussed, but in discussions of some historical events it has been necessary to refer to the Bureau of Land Management and the U.S. Geological Survey in their former capacities to avoid confusion. The reader should keep in mind that all of the OCS activities of these latter two agencies have now been transferred to the Minerals Management Service.

EXECUTIVE SUMMARY

INTRODUCTION

Given the high price of oil, the vulnerability of the country to foreign supply disruptions, and the priorities of the Reagan Administration, there has been growing interest in developing the potential hydrocarbon reserves of the U.S. continental shelf. OCS Lease Sale No. 56, the first off North Carolina, was held in August of 1981. Forty-three tracts off the state were leased, for a total of accepted high bids of $341 million. A re-offering of Sale 56 tracts, held in August 1982, resulted in the leasing of an additional six tracts for $3.4 million. The next sale for North Carolina tracts will be No. 78, scheduled for July 1983. This will be the first of the new area-wide lease sales in the southeast Atlantic and will include roughly twenty times as much acreage as was offered in Sale 56.

If oil or gas is found off North Carolina in commercial quantities, it must be transported to shore. If oil reserves of small size are found, given the distance from shore, it is likely that the oil will be loaded into tankers in the fields for direct shipment to existing refineries. Should considerable amounts of oil be found, however, the companies involved will prefer to pipe it to shore at a major port (Norfolk, Morehead City, or Wilmington), where it would be loaded into tankers for shipment elsewhere. Natural gas, on the other hand, can only be transported economically by pipeline. Any gas pipeline from offshore North Carolina would almost certainly pass inland through the state to feed into the Transco (Transcontinental Gas Pipe Line Corp.) transmission lines running northeast through the Piedmont.

There are no hydrocarbon pipeline landfalls currently in the state and very few major lines in any part of coastal North Carolina. As a result, public resource managers and coastal residents have virtually no experience with these types of facilities. Concern about the potential impacts of pipelines, and particularly the need to examine routing issues early in field development, led the state to fund this project through the Coastal Energy Impact Program.

PROJECT OBJECTIVES

The study was designed to meet three basic objectives:

1) To identify and analyze the principal environmental and economic impacts and the technical and legal variables involved in constructing oil and gas pipelines;
2) To design strategies for preventing, reducing or ameliorating potential losses of valuable coastal environmental and economic resources; and
3) To provide the results of these analyses to state decision makers and other interested parties in a comprehensive but readable document.

The report was written with two different scales of analysis in mind. At one level, the report is intended to assist those making decisions at the state-wide or coastal-zone-wide level regarding state policy towards OCS pipelines. The second level is at the scale of a particular resource or

activity, where the report is designed to provide background and references to agency personnel to assist them in making informed judgements on specific permit applications.

PHILOSOPHY AND APPROACH

There are three groups of considerations that should enter into government decisions regarding pipeline siting:

- What are the expected impacts of pipeline installation and normal operation on various environmental resources and economic activities along the proposed route?
- What environmental conditions (both natural and man-made) along the route pose a threat to pipeline safety?
- What resources along the route will be damaged in the event of a pipeline break, and what will be the extent of that damage?

The first two questions have been addressed in detail in the following report. The third question might easily have required another report of at least equal size; because there is an extensive literature on oil spill impacts, and because the impacts of natural gas leaks are expected to be minimal, at least offshore, the report does not address this subject in as much detail.

A basic conclusion that was reached early in the study was that the areas that might be damaged significantly by pipeline construction activities or that create hazardous conditions for pipelines are relatively small in relation to the total land and water area of the coastal zone. As a result, instead of attempting to designate long, narrow corridors to which pipelines would be restricted, it makes more sense to consider designating sensitive areas as "exclusion" or "avoidance" areas. Such an approach, we think, would provide the state with a more flexible framework within which to respond to pipeline route proposals, while still adequately protecting those resources deserving protection.

The report has been organized to reflect this approach. After an introductory chapter, the next three chapters provide basic information on oil and gas activities off North Carolina (Chapter II), pipeline construction methods (Chapter III), and the legal environment (Chapter IV). Chapters V-IX analyze the various geological conditions, environmental resources, and economic activities that should be considered in pipeline siting.

The study was conducted using existing sources of information and did not entail any experimental research. A variety of information sources were consulted, including the available literature and various coastal scientists, policy makers, and industry engineers, both within North Carolina and in locations with pipeline experience, particularly Louisiana. Two advisory committees, one made up primarily of potential users, and another of people with technical proficiency in the subjects covered in the report, provided a number of valuable suggestions.

PIPELINE CONSTRUCTION AND OPERATION

Pipeline systems typically consist of several major components: a hydrocarbon source and destination, a main or trunk line that transports the hydrocarbons, gathering lines that collect them from the producing field and feed them into the trunk line, and various ancillary facilities along the

route, including an initial pressure source (if needed), intermediate pressure booster stations, processing facilities, and various valves and meters.

Pipelines are laid within a right-of-way that is usually acquired as a perpetual easement or lease from the original landowner, be it a public agency or private citizen. Rights-of-way for large-diameter pipelines are typically about 100 feet wide during construction and are reduced to roughly 40-50 feet in width when installation is complete.

The choice by industry of a preferred route is based on several considerations, most of which have in common the primary goal of minimizing the life cycle costs of the system. Total pipeline length, offshore length, and the location of a suitable landfall are among the most important criteria. Other criteria include topography, soil conditions, the presence of potential hazards, regulatory restrictions and procedures, and land acquisition costs (particularly delay).

Once the route has been selected and the necessary easements and permits acquired, construction can begin. The standard method for constructing large-diameter lines offshore is to weld sections of pipe one at a time onto the line on a large barge (known as a lay barge); as each section is added, the barge moves forward, slowly lowering the line to the seafloor. If burial is necessary (as it often is nearshore), one of several methods is used, depending on substrate conditions.

Laying the pipeline across the land-sea interface is particularly time-consuming and expensive. The line is assembled either on land or on a barge, and either pulled or pushed into position or laid in a canal dug for the lay barge to operate in, depending on conditions at the landfall. These methods are described in the main report. Onshore, the line is constructed by a "spread" consisting of different teams that perform their tasks sequentially as they move along the line, from right-of-way clearing, through pipeline welding and burial, to final clean-up.

Once the line is in operation, activity and manpower requirements drop off substantially. In addition to the day-to-day operations of the pump or compressor facilities, the major activity is monitoring of the line to prevent and detect leaks. Leak detection is an imperfect art, and a number of different measures are used together to minimize the amount of oil or gas that may escape before the leak is detected.

LEGAL REQUIREMENTS

OCS pipelines built through coastal North Carolina face a plethora of legal hurdles that for purposes of discussion have been divided into three groups:

1) Procedures for acquisition of pipeline rights-of-way;
2) Permits and regulations for environmental protection that will influence pipeline location and construction methods; and
3) Pipeline safety regulations concerning line design, construction and operation.

Pipelines crossing from the Outer Continental Shelf into North Carolina will be considered interstate lines, and therefore will be subject to federal regulation of such lines as well as relevant state and local regulations.

All subtidal bottomland is owned either by the federal government (seaward of the three-mile limit) or state government (within three miles of shore), and easements to lay pipelines across these lands must be obtained from the Minerals Management Service and/or N.C. State Property Office, respectively. Onshore, easements across public lands are granted by the agency managing the parcel, be it the Department of Defense, the Department of Interior, the N.C. State Parks System, a municipal government, or other agency. Easements across private lands may be obtained either by negotiation or through eminent domain, which authority is granted to hydrocarbon pipeline companies by North Carolina and federal statute.

In addition to the reviews that will be conducted in connection with the granting of these easements, other regulatory measures have been enacted to help minimize the impacts of such facilities on the natural environment. These are described at length in the main report; they include state and federal environmental impact statement requirements, the Corps of Engineers' Section 10 and 404 permits, various OCS Lands Act regulations, the N.C. Coastal Area Management Act regulatory program, the state's dredge and fill, sedimentation control, and water quality regulations, and others. The net result of these various programs is that North Carolina state and federal agencies together possess sufficient regulatory authority to eliminate virtually all environmental and economic impacts deemed not in the public interest, with the possible exception of onshore oil lines. This is not to say such authority will necessarily be used to do so.

Finally, interstate pipeline design, construction, and operation is largely regulated by the U.S. Department of Transportation, and additionally for offshore lines by the Department of Interior.

GEOPHYSICAL HAZARDS AND CONSTRAINTS

The presence of certain geological and physical conditions, particularly in the offshore region, will have an important influence on pipeline design, location, and safety. In the main report, the geological and oceanographic conditions of the North Carolina shelf are reviewed, particularly those relevant to pipeline siting. These are:

- sediment conditions, particularly the absence of unconsolidated sediments over large portions of the shelf, especially Onslow Bay;
- the potential occurrence of sediment instability, resulting in slumps, debris slides, sand waves, scour, and liquefaction;
- tectonic activity, including both fault movement and ground shaking as a trigger for sediment liquefaction or submarine slides; and
- coastline instability, including both inlet migration and erosion of the seaward coastline.

There is a significant dearth of information regarding seafloor conditions over much of the North Carolina shelf. What there is suggests that conditions that would cause concern for pipelines are not widespread, with the exception of rock outcrops and hard grounds, and there do not appear to be any insurmountable obstacles to laying pipelines over much of the shelf off the state. Detailed route surveys will of course be needed and are required by MMS as part of their easement application process.

ENVIRONMENTAL RESOURCES

The study examined a wide range of environmental resources in coastal North Carolina for their sensitivity to pipeline installation and operation. In general, certain pipeline activities generate the majority of impacts; these are:

- the burial of pipelines in subaqueous environments, with its associated bottom disruption, turbidity, and sedimentation;
- the dredging of flotation canals in shallow open water areas;
- the dredging of pipeline canals through marshes;
- the removal of all vegetation within the onshore right-of-way during construction, thereby destroying habitat and exposing soil to accelerated erosion; and
- the permanent suppression of tree growth within the permanent right-of-way.

Certain environments, particularly the more productive or fragile natural systems, will be more affected than others, and these areas are the basis for the recommendations regarding pipeline siting presented in Chapter X.

It is important to place the amount of potential impact in perspective, however. Shrimp trawling in North Carolina's inside waters annually disturbs a far greater volume of sediment than would be disturbed by a number of major pipelines. Hundreds of miles of mosquito ditching already lace North Carolina marshes. Road construction causes more onshore habitat disruption than does construction of large-diameter pipelines. Such comparisons cannot serve as excuses, however. Even incremental changes may have substantial impacts on certain natural systems. Furthermore, the state should plan for not one or two, but many pipelines, and should consider the possibilities of cumulative impacts beginning with the first application.

One of the major findings of the study is that the choice of a route often has less to do with the amount of total environmental impact than do the construction and restoration methods used. Since the latter will be specific to certain environments, it does not make sense to talk about routing independently of these other considerations. As a result, throughout the discussions of environmental resources, appropriate precautions and mitigation measures that can be taken are described. Certain general principles emerge: these include the proper timing of construction activities, rapid restoration of the area disturbed, and maximal use of previously disturbed areas and existing rights-of-way.

RESOURCE USES

Many economic activities and resource uses in the coastal area may be disrupted by careless pipeline practices. A number of these were examined in the study, including commercial and recreational fisheries, shipping, mining, military programs, the preservation of cultural resources, onshore transportation and utilities, parks and recreation, and wildlife refuges. While the extent of impact naturally varies among the different activities, two general conclusions stand out:

1) Some degree of disruption, or at least potential for disruption, is unavoidable for all of these activities; and

2) Through careful planning and adequate precautions to protect the natural resource base, disruptions can be kept to relatively minor levels.

Furthermore, in many cases where impacts cannot be avoided, appropriate levels of compensation can at least eliminate the financial burden that would otherwise be borne by other parties.

CONCLUSIONS

In Chapter X the basic conclusions of the report regarding pipeline siting and mitigation of construction impacts are presented. The major siting recommendations are listed as a table of the various environmental features to be considered, primarily for avoidance, in choosing pipeline routes. In addition, it is recommended that no long pipeline corridors be specifically designated by the state, but rather that the state designate "avoidance areas" or "windows" around such areas, at least where the dimensions of such areas are more than 5 to 10 miles.

Several measures to reduce construction impacts, generalized from the discussions of the previous several chapters, are also presented. These are:

1) Minimize the size of the area affected by construction and operation activities.
2) Choose the least damaging construction alternative where technical and economic factors permit.
3) Schedule construction and operation activities seasonally to avoid sensitive resources.
4) Restore the disturbed area as rapidly and completely as possible.
5) Consider ways to make creative, positive use of the pipeline and its by-products.

Two folded maps also accompany the report. They provide an overview of the location of features sensitive to or hazardous to pipelines in coastal North Carolina, and include all such features for which reliable data covering the entire coastal zone are available. The data are divided into two sets: natural features and biological resources are shown on the first map, and economic or cultural uses of the coastal zone on the second.

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I. INTRODUCTION

1.1 BACKGROUND

The discovery of oil and gas potential on the U.S. Atlantic Outer Continental Shelf has accelerated leasing and exploration activities along the East Coast from Georges Bank to Florida. Six lease sales have been conducted to date in these frontier regions. Gas discoveries have been made off the New Jersey coast, though not yet in sufficient quantities to justify development and production. Dry wells resulted from Sale 43 off Georgia, and exploratory drilling began recently on Georges Bank and will soon be underway off North Carolina.

There is substantial concern among coastal states regarding the potential hazards and adverse environmental, social and economic impacts of offshore oil and gas development. Surveys and workshops conducted by the Federal Office of Coastal Zone Management and the Bureau of Land Management have been used to compile a priority list of the policies and concerns of the coastal states susceptible to impact from OCS development (USDOC/OCZM, 1977). The five highest priority items expressed by the State of North Carolina were:

- Protection of the future potential of the fishing and tourist industry;
- Protection of the environment, especially the resources on which fishing and tourism are based (e.g., wetlands, marshy areas, beaches, etc.);
- Assuring distribution of OCS petroleum revenues to affected states;
- The need for planning and management of the cumulative adverse impacts of the OCS petroleum lease sales in each leasing region;
- Protection from and investigation of the impacts of massive and chronic oil spills.

Other expressed concerns related to the state of completion of environmental baseline studies adequate to evaluate the potential impacts of oil development activities or an accidental discharge.

A major concern of some states has been the potential impact of oil and gas pipelines built to transport OCS production to shore. Several studies have been conducted by public agencies on the East coast to examine potential pipeline impacts and to explore routing options in particular areas (see Rooney-Char and Ayres, 1978; Golden et al., 1980; Gowen et al., 1980). Similar concerns in North Carolina led officials of the state's Department of Natural Resources and Community Development to fund a comparable study for the State of North Carolina. The purpose of this study has been to assemble for state decision makers and coastal planners information on the potential conflicts and impacts of pipeline construction and operation in North Carolina's coastal zone, with special emphasis on the siting implications of this information. This document constitutes the study's final report. The project was conducted by the North Carolina State University Department of Mechanical and Aerospace Engineering, supported on a subcontract basis by the Raleigh, North Carolina, office of Science Applications, Inc.

1.2 PURPOSE AND SCOPE OF STUDY

The purposes of the study were threefold: 1) to analyze the principal environmental impacts and technical variables involved in coastal pipeline

construction and operation; 2) to study and design strategies for preventing, reducing, or ameliorating potential losses of valuable coastal environmental and economic resources; and 3) to provide the results of these analyses to state decision makers and other readers in a document for use in evaluating proposed pipeline routes and in understanding the technical and regulatory context of pipeline construction and operation. The primary audience of the study is the group of state decision makers in the Department of Natural Resources and Community Development, the State Property Office, and elsewhere, who will rule on permit applications submitted by pipeline companies. It is hoped and intended that a wider group of people and organizations will also find this document useful, including industry, local officials, environmental groups and interested citizens.

It was the original intent of this project to evaluate and recommend specific corridors through the state's coastal zone into which OCS pipelines would be directed. As the study proceeded, however, this approach became increasingly impractical for several reasons. The locations of pipeline termini (both offshore and onshore) can only be guessed at this time, and with Lease Sale 78 less than a year away, the number of potential offshore termini is large. Furthermore, many of the adverse impacts of pipeline installation in various environments can be eliminated by the proper timing of construction activities, the choice of construction methods and other techniques, as this report will demonstrate. As a result, the potentially major route relocations implicit in the selection of a few pipeline corridors are not justified for the most part by possible environmental or economic impacts. Instead, the approach of the study was shifted to focus on identifying the various features that may be affected by pipeline construction and operation, and to present this information in terms of the relative degree of impact involved in siting pipelines through these areas. Rather than attempting to identify preferred pipeline routes, then, we have attempted to identify areas preferably avoided. It was felt that such an approach would result in a report that could be used more flexibly in responding to different pipeline route proposals.

The geographic scope of the report includes the state's twenty-county coastal area (as defined in the North Carolina Coastal Area Management Act of 1974) and the coastal and offshore waters extending out to the lease sale area. While gas pipelines may extend inland of the coastal counties, the principles involved in siting pipelines in these areas will be much the same as those in the coastal area, and it was deemed impractical to extend the project's coverage to an area as large as the eastern two-thirds of the state.

1.3 LAYOUT OF THE REPORT

The purpose of the report's next three chapters is to inform the reader about the context in which pipelines will be built in coastal North Carolina. Chapter Two presents background information on the lease sales that have been and will be conducted off North Carolina and on the hydrocarbon transportation needs that may result. Chapter Three provides an overview of how pipelines are designed, built and operated, in both offshore and onshore environments. The chapter is based on the premise that an understanding of the basic technical aspects of pipeline construction and operation is necessary to understand the potential impacts and hazards of pipeline construction and operation. In Chapter Four, the overall legal context in which pipelines from the OCS are built and operated is discussed. As the number of statutes

affecting pipelines is large, only the major statutes and authorities are discussed here, while many of the laws protecting specific environmental resources or resource uses are mentioned in the various sections of Chapters Seven and Eight.

The remainder of the report is devoted to a discussion of the various impacts, conflicts and concerns involved in siting, constructing and operating pipelines in coastal North Carolina. The discussion is divided into three major sections that focus on the geological and physical, the environmental, and the cultural features of concern (the latter term refers to human uses of the environment that may conflict with pipelines). Discussions of pipeline breaks, ancillary pipeline facilities, and the use of existing rights of way are also included. A final chapter presents the study's conclusions and recommendations.

II. THE NORTH CAROLINA SETTING

2.1 PRESENT AND UPCOMING OIL AND GAS ACTIVITIES OFF THE NORTH CAROLINA COAST

OCS Sale 56. Outer Continental Shelf Lease Sale No. 56, held on August 4, 1981, offered a total of 285 tracts for leasing off the coasts of North Carolina, South Carolina, Georgia and Florida. This was the second sale of leases on the South Atlantic OCS, and the first for tracts off North Carolina (see Figure 2-1).

Of the 130 tracts offered off North Carolina, bids were received for 50 tracts, and the high bids for 43 of these were accepted by the U.S. Geological Survey (Table 2-1 provides a summary of the sale and a listing of the high bids accepted). The tracts leased were each 2304 hectares (5693 acres) in area, and ranged from 32 to 111 nautical miles from shore, in water depths of 200 to 1850 meters. All leases are for an initial term of ten years.

Reoffering Sale RS-2. Reoffering Sale RS-2 was held in August 1982. Among the tracts offered were 81 of the 87 Sale 56 tracts not leased off North Carolina (the six tracts near Cape Lookout were not included). Of these, seven were bid on, and six of those bids were accepted, for a total of $3.375 million (Table 2-2).

Future Sales. OCS Sale No. 78 is tentatively scheduled for July 1983 and will be the first of the new area-wide lease sales in the South Atlantic region. The area proposed for leasing (Figure 2-2) extends from the Virginia line south and southeast to Florida, covering roughly 33 million acres and 5800 lease tracts (as compared with 1.6 million acres and 285 tracts offered in Sale 56). Tracts off North Carolina extend as much as 100 miles further offshore and into far deeper waters than tracts leased in 1981.

Under the proposed Five-Year Leasing Program announced in March 1982, additional sales for the South Atlantic region (Nos. 90 and 108) are tentatively scheduled for January 1985, and January 1987, respectively. As the calls for information (the first step in the process of selecting tracts to offer for leasing) will not be issued for some time yet, it is not presently known whether these sales will include tracts off North Carolina. This will depend in part on exploration results from Sales 56 and 78.

2.2 POTENTIAL ALTERNATIVES FOR OFFSHORE OIL AND GAS TRANSPORTATION

If oil is found offshore in commercial quantities, there are two basic alternatives for transportation to shore: tankers and pipelines. Several factors together determine which alternative is preferred. These include the size of the reserves, the dispersion and distance from shore of the production areas, meteorological and oceanographic conditions, the ultimate destination of the crude oil, and the availability of oil terminals (NERBC, 1976).

Tankers will be preferred when the quantities of oil are small, the production areas are scattered and far from shore, and bottom conditions are not conducive to pipeline construction. In this case, offshore storage and terminal facilities near the producing fields will be used to transfer the crude oil to shuttle tankers for direct transport to existing refineries. If

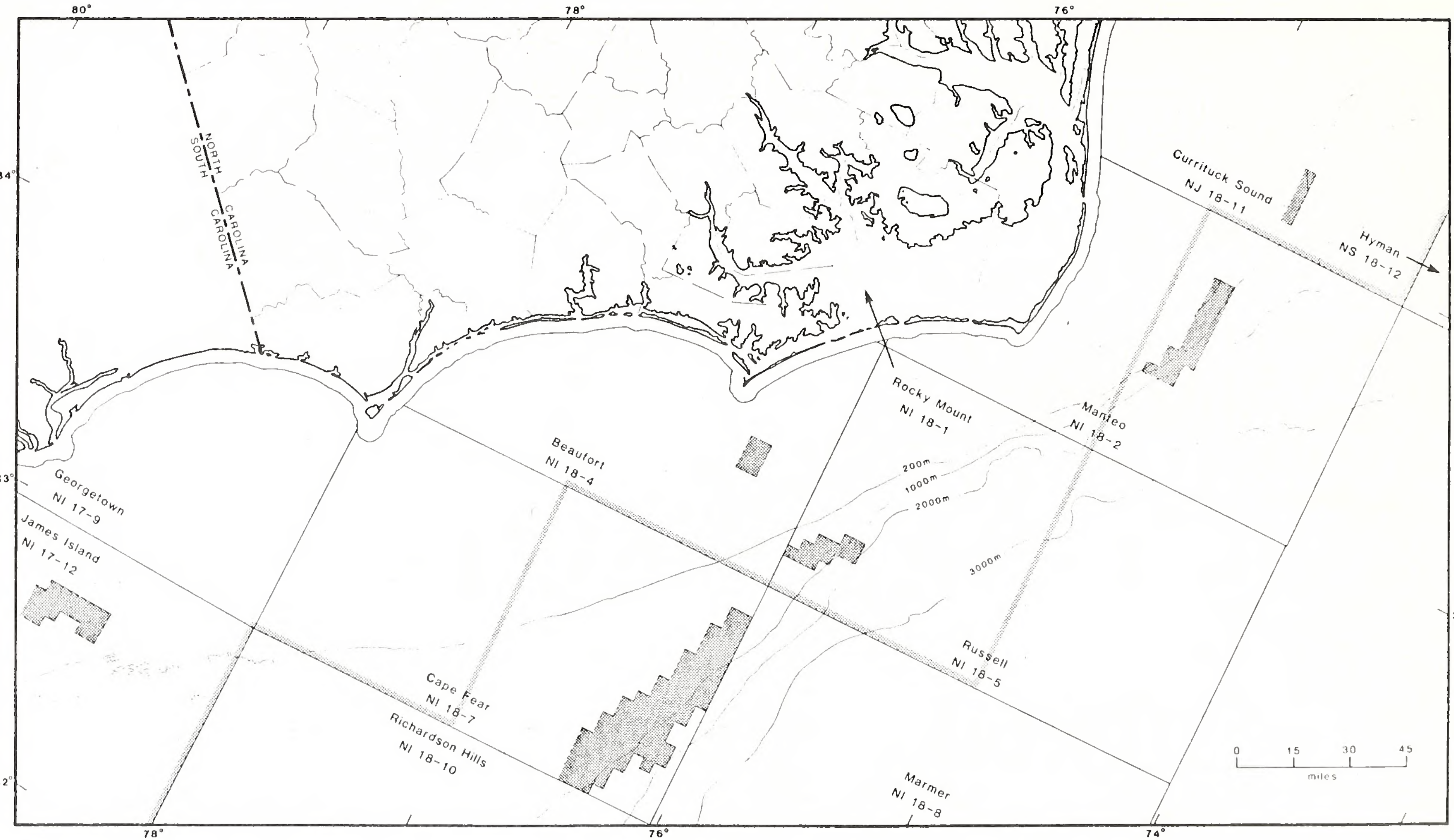
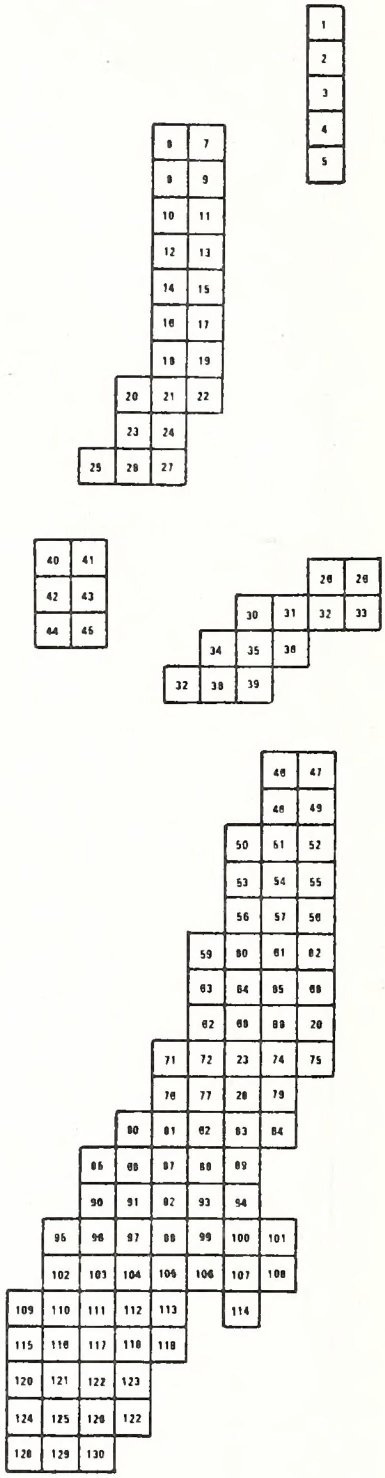


Figure 2-1. Tracts offered off the North Carolina coast in OCS Lease Sale 56, August 1981.

Table 2-1. OCS Lease Sale 56 summary for tracts off North Carolina.

Tracts offered	130
Tracts bid on	50
Tracts for which bids accepted	43
Total accepted high bids	$341,013,174



Tract	Bid	Company(ies) with accepted high bid
1	$15,724,000.	Mobil, Amerada Hess, Marathon
2	3,600,000.	Conoco, Union, Chevron
3	7,230,000.	Conoco, Union
4	816,000.	Conoco, Union
5	816,000.	Conoco, Union
6	217,000.	Conoco
7	456,000.	Conoco, Union, Chevron
8	217,000.	Conoco
9	456,000	Conoco, Union, Chevron
10	515,000.	Conoco, Union
11	623,000.	Conoco, Union
12	2,340,000.	Conoco, Chevron
13	6,840,000.	Conoco, Union, Chevron
14	8,120,000.	Conoco, Chevron
15	28,512,000.	Mobil, Amerada Hess, Marathon
16	16,600,000.	Union, Chevron
17	103,775,000.	Mobil, Amerada Hess, Marathon
18	26,374,000.	Conoco, Chevron
19	33,130,000.	Mobil, Amerada Hess, Marathon
20	650,000.	Conoco, Union, Chevron
21	53,627,000.	Mobil, Amerada Hess, Marathon
23	3,600,000.	Conoco, Union, Chevron
24	7,515,000.	Conoco, Union
25	217,000.	Conoco
28	2,346,000.	Atlantic Richfield, Murphy, Odeco
29	408,000	Atlantic Richfield, Murphy, Odeco
31	728,000	Chevron
32	428,000.	Chevron
52	489,000.	Union
67	517,000.	Conoco, Union
68	1,510,000.	Union
72	434,000.	Shell
77	587,000.	Shell
84*	625,720.	Culf, Amoco
100*	237,888.	Murphy, Odeco
101*	559,000.	Cetty
104*	746,390.	Gulf, Amoco
107*	237,888.	Murphy, Odeco
108*	237,888.	Murphy, Odeco
125*	2,754,400.	Culf, Amoco
126*	2,754,400	Culf, Amoco
129*	2,222,200	Culf, Amoco
130*	1,220,400	Culf, Amoco

* Leases include fixed net profit share of 30 percent and 1.50 capital recovery factor; other leases with fixed royalty payments of 12.5%.

Table 2-2. OCS Reoffering Sale RS-2 summary for tracts off North Carolina.

Tracts offered	81
Tracts bid on	7
Tracts for which bids accepted	6
Total accepted high bids	$3,375,150

Tract	Bid	Company with accepted high bid
27	$1,713,000	Shell
73	208,000	Shell
78	152,000	Shell
97	150,150	Gulf
121	151,000	Shell
122	151,000	Shell

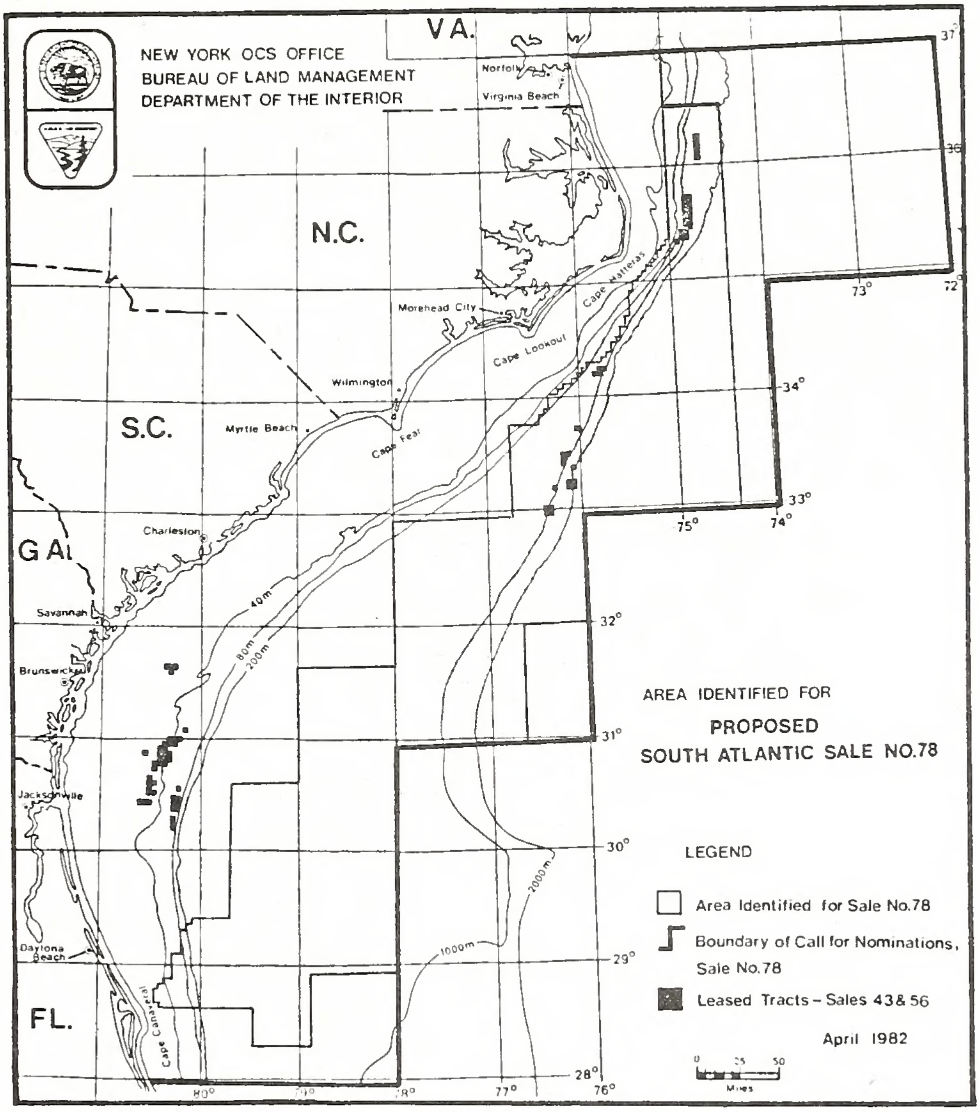


Figure 2-2. Proposed South Atlantic Lease Sale No. 78.

the quantity of oil is larger or the refineries remote, shuttle tankers may transport the oil to nearby, onshore marine terminals for transshipment by larger tankers or overland pipeline. Marine pipelines, on the other hand, will be the preferred choice for crude oil transport when the reserves are large, production areas are in clusters and close to shore, onshore terminal facilities exist, and/or meteorological conditions make continuous tanker operations difficult. The controlling factor is the economics of the various alternatives: in most cases pipelines are preferred if oil or gas is found in sufficient quantities to justify the substantial investment a pipeline requires.

Because the expense of liquefying natural gas on offshore platforms for shipment by tanker is prohibitively large, pipelines are currently the only alternative for transporting natural gas to shore. A substantial gas find is needed to justify pipeline construction. Gas wells with insufficient showings are plugged with the hope that future discoveries or price increases will make development economical. Small amounts of natural gas produced with oil may be reinjected into the reservoir or flared.

In the U.S., pipelines transport all of the natural gas and most (95%) of the oil produced offshore (Shanks, 1978). For Sale 56, the BLM estimated that if all tracts off North Carolina were leased and developed, the USGS low estimate of hydrocarbon reserves would result in no pipelines being built, while their high estimate would result in one oil and one gas pipeline.

An offshore pipeline system, whether oil or gas, typically has several components. Gathering lines are small-diameter pipelines that gather oil or gas from individual production platforms; they feed into large-diameter trunklines which transport the oil or gas to shore. Ancillary facilities, which may include a pressure source at the production platform, one or more intermediate pressure booster stations, and various onshore processing facilities, are located along the pipeline route.

2.3 POTENTIAL INLAND DESTINATION POINTS FOR OCS OIL AND GAS PIPELINES

A major factor in deciding whether and where to build a pipeline is the location of potential or existing onshore facilities for handling the oil or gas. Crude oil is ultimately transported to refineries. Where refineries on the nearby coast are lacking, inadequate, or unavailable for various reasons, a marine terminal may be constructed near the pipeline's landfall, or an overland pipeline may be built to transport the oil to existing refineries or crude oil pipelines inland. Marine terminals consist of tank farms, where the incoming crude oil is stored, and loading facilities where the oil is loaded into tankers for shipment to other refineries.

Currently there is only one small refinery on the Carolina coast, a 12,000 barrel-per-day facility in Wilmington operated by ATC Petroleum. Two larger refineries were proposed recently for Brunswick and Carteret Counties, but both have been cancelled because of weak market conditions, environmental opposition and other factors. There are several marine terminals on the North Carolina coast. Most are in the Wilmington area and are operated by Exxon, Mobil, Shell, Texaco and others; they are used for the unloading, storage and distribution of petroleum products. As an indication of the activity of these terminals, a total of 311 tanker ships and 792 tanker barges entered the Port

of Wilmington in 1979, bound for these terminals (U.S. Army Corps of Engineers, 1981). In addition, an aviation fuel terminal is operated on Radio Island in Morehead City Harbor. There is only one small crude oil terminal in North Carolina, servicing the refinery in Wilmington mentioned above. There are no crude oil pipelines within or even near the state.

Unless unexpectedly large oil discoveries are made, it is unlikely that a refinery would be built in North Carolina to process OCS oil production. It is more likely that the oil will be shipped to existing refineries, so that, if an oil pipeline is built to shore, it will terminate at a marine terminal somewhere along the coast. Wilmington, Morehead City, and Norfolk, as the three deep-water ports closest to the lease areas, are likely candidates for the terminal's location.

There are theoretically two alternatives for the terminus of an OCS gas pipeline. The pipeline could terminate at a coastal liquefaction plant, where the gas would be liquefied and shipped by tanker to other ports, but the cost of this option and the availability of an onshore market make this alternative very unlikely. Instead, the virtually certain alternative is that a gas pipeline would continue inland to connect to the nearest commercial transmission line capable of transporting the gas to an acceptable market.

The Transcontinental Gas Pipeline Corporation (Transco) is the only interstate gas transmission company operating in North Carolina, and it is the only carrier in the state capable of transporting the quantity of gas necessary to justify pipeline construction (although a portion of OCS production could be sold to N.C. intrastate gas companies). Transco's array of trunklines passes northeast through the western Piedmont (Figure 2-3), and a pipeline carrying OCS gas production would have to connect with these lines. The most likely connection point is at a compressor station, of which there are four in North Carolina: in southeastern Cleveland, southern Iredell, northeastern Davidson and central Rockingham Counties. Alternatively, depending on the offshore origin of the line, one of the compressor stations in southern Virginia might be a closer destination. One possibility is that an OCS pipeline could be built within or adjacent to the right-of-way of Transco's 20-inch spur line that leaves the main lines at the compressor station in Pittsylvania County, Virginia, traveling east and southeast into North Carolina, and terminating as a 12-inch line at Ahoskie in Hertford County.

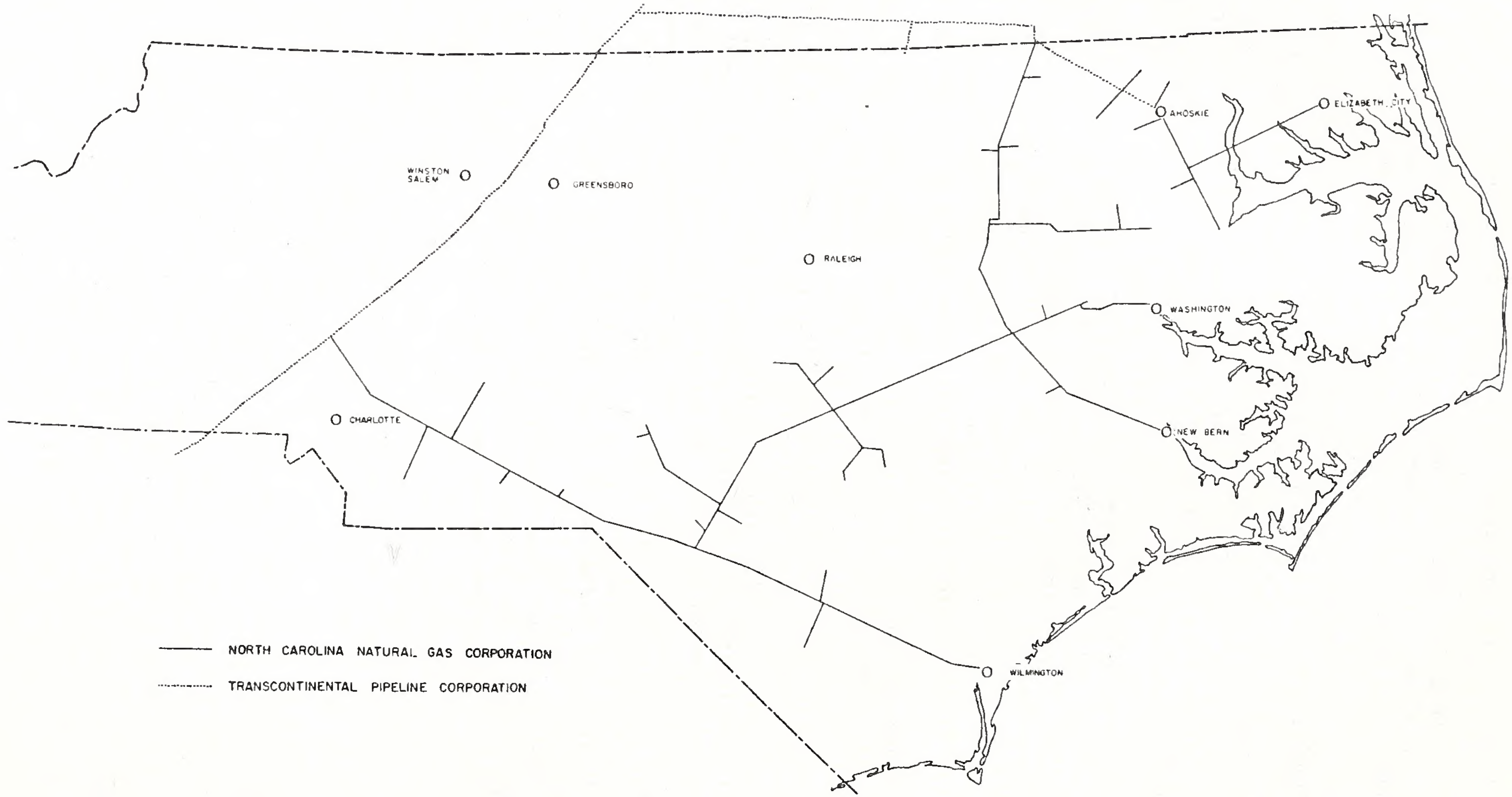


Figure 2-3. Major interstate and intrastate gas transmission lines serving coastal North Carolina.

III. PIPELINE CONSTRUCTION AND OPERATION

3.1 PIPELINE SYSTEMS

Producing wells on the OCS clearly must have some cost effective way of delivering their product to refineries or gas processing facilities.

If the field is to be economic in operation, large quantities of product must be transported inland. For petroleum producing wells, the operator has two methods of delivering the oil to the desired locations. These are shipment by crude oil tankers, or transport through an offshore/onshore pipeline system. Indeed the desired delivery point may change with the method of transportation that is selected.

The selection of tankers versus pipelines depends on a number of factors, some of which are: (1) the location of the facility at which the oil will be totally or partially processed; (2) the physical oceanographic conditions (waves, winds and currents) likely to occur at the producing field or tanker loading point; and (3) the expected volume of oil that the field will produce. In North Carolina there are no refineries located near any of the potential OCS well sites, thus it is most likely that the oil will be either transported by tankers to distant refineries or will be piped to partial processing facilities located somewhere near the landfall site. From these facilities it would then be transported to refineries to complete the processing operation.

In addition to geographic factors, the choice of method of transportation will also depend on the oil company which owns the producing well, the facilities to which they have access, and the general philosophy of the company.

In contrast to petroleum, production from gas wells will almost certainly be transported by a pipeline or pipeline system. The natural gas must be treated before it is shipped to utility companies, but untreated gas can be transported without difficulty. Therefore, the location of a natural gas separation and dehydration plant relative to the pipeline landfall is much less critical (e.g., it can be further inland). The situation can be further complicated by OCS fields from which a combination of oil and gas are transported inland through a single main trunkline (mixed phase pipeline).

For the purposes of this report, the pipeline system is defined as the main trunkline from the OCS field to its onshore location, the driving or pressure source(s), and the gathering lines within the OCS field. In many cases the company that owns the producing wells will not directly own all or any part of the pipeline system. The reasons for this are discussed later. However, there must be a reasonably close business relationship between the owners of the pipeline system and of the wells.

3.1.1 Components of Pipeline Systems

The major components of a pipeline system are the gathering lines from individual wells, pressure booster stations at the beginning and possibly intermediate points along the pipeline, the main trunk pipeline(s), and the landfall and onshore facilities. These sources are described briefly below.

Gathering Pipelines. In multi-platform fields, a number of smaller diameter gathering lines are utilized to bring the product to a single point for transportation to shore. The gathering lines will be present even if tanker transport to shore is utilized for oil. The gathering lines are usually owned and operated by the well operator and are operative under different regulatory guidelines than the main trunk line.

Pressure Booster Stations. All pipeline systems require some pressure source to drive the fluid through the pipeline system. Petroleum pipelines utilize pumps, whereas gas pipelines utilize compressors. Mixed phase pipelines obviously require a combination pressure source system which is generally of lower efficiency than a pump or compressor alone. This is one reason (but not a major one) why separate oil and gas pipelines are usually constructed, given a reasonable amount of product. Depending on the length and diameter of the pipeline, the product being transported, and the topography of the route, intermediate pressure booster stations may be needed to maintain product delivery rate. For offshore main trunk pipelines, intermediate pressure booster stations on separate platforms are usually avoided if possible because of high costs, maintenance and repair requirements, and the potentially reduced reliability resulting from such intermediate stations.

Main Pipelines. The main pipeline is the line between the final gathering point in the OCS field and the onshore facility to which the product is being transported. These pipelines are designed, operated and maintained to meet the specifications of Title 49, Parts 192 (for gas lines) and 195 (liquid lines) of the Code of Federal Regulations. Recommended industry practice for OCS pipeline construction and operation may be found in the American Petroleum Institute (API) publication API RP 1111 "Recommended Practice for Design, Operation and Maintenance of Offshore Hydrocarbon Pipelines," American National Standards Institute (ANSI) codes ANSI B31.4 "Liquid Petroleum Transportation Piping Systems," and ANSI B31.8 "Gas Transmission and Distribution Piping Systems;" in many cases these recommended standards have been incorporated by reference into the federal regulations. The system's required capacity is the major determinant of pipeline design criteria and of the ultimate cost of the pipeline.

It is clear that the construction and maintenance costs of offshore pipelines will be considerably greater than those for an onshore pipeline. Because of this, it is customary to believe the offshore pipeline route will be made as short as possible. While this practice is generally adhered to, there are a number of regulatory factors as well as the cost and availability of suitable landfall sites that prevent this from being a universal rule.

Landfalls and Destinations. The landfall is the site at which the pipeline comes onshore. The environmental and social impacts (and costs) of pipelines are likely to be highest at or near the landfall site. The availability and cost (both economic and social) of the landfall site can often be one of the major considerations in determining a pipeline route. As previously discussed, oil pipelines require that pumping stations and storage facilities be located as near the landfall as practical. The product is then transported by an onshore pipeline or other means to a refinery. With gas pipelines, more flexibility is possible in the location of the pressure booster station and processing facilities. These are usually located overland

between the landfall site and the nearest commercial gas transmission line. Offshore gas pipelines must eventually be connected directly to an onshore gas transmission line.

3.1.2 Ownership and Operating Patterns

Pipeline systems are usually owned and operated by wholly owned subsidiaries of major shippers and marketers of oil and natural gas. When more than one company is interested in a new pipeline system, there are three possible alternatives to ownership: an undivided interest system, a separate corporation, or a different pipeline for each company (Petroleum Extension Service, 1973).

For the undivided interest system each participating company owns a fixed percentage of the pipeline capacity and is responsible for a corresponding percentage of capital and fixed operating costs. Costs such as power and other variable costs that are related to actual usage are usually prorated for the particular company's throughput over a given period of time. One of the participating companies usually serves as agent-operator for the pipeline. Each company issues a tariff for use of the portion of capacity it owns, and the revenue and expense are combined as part of the company's overall business in computing its profit or loss.

A separate corporation is a new corporation that is formed with the parent companies having stock options, usually in approximate proportion to their expected use. The corporation may be agent-operated or fully staffed but operates as a separate business entity, charging and collecting tariffs on all throughput and paying the operating expenses. The profit or loss of the operation is then transferred to the company stockholders as with any other corporate entity. The economic earnings position of most pipeline companies generally makes the individual interest system financially more advantageous than a separate corporation (Petroleum Extension Service, 1973).

The system by which each company builds its own system is usually only justified when the shipper has sufficient product to completely fill the largest pipeline that can practically be constructed. In recent years, the maximum size of pipelines has increased considerably above the capacity of a single producer, and so multi-owner, large capacity systems are common for the transport from supply to consuming areas. For marine pipelines, the capacity is set by the anticipated capacity of the offshore field, and the choices may be different. Moreover, as regulatory and permit procedures become more involved, as with marine pipelines, the incentive is decreased for each company to acquire its own right-of-way and construct its own pipeline.

Future arrangements will most likely be based on a combination of technical and engineering design requirements, regulatory and permit considerations, and federal and state financing, tax, and corporate laws.

3.2 PIPELINE PLANNING AND ROUTE SELECTION

A brief description of the planning and design process, primarily as it relates to route selection, is provided. The process starts with an estimate of the expected production rate and starting location of the product and subsequently the destination of the product. From a simplified view, a route

is then selected to minimize total cost, time required for construction (a factor in total cost), and environmental impact. As previously stated, this is somewhat simplified, because the destination of the product may depend on costs and environmental impacts associated with the route to the destination. The planning, design and route selection steps are a continually evolving process with considerable interaction. However a description of the major features is provided.

3.2.1 The Design Process

The pipeline diameter is the major preliminary design parameter in the design process. It is determined primarily by the type of product (oil or gas), the flow requirements, and the pipeline length and design pressures. It is also dependent to a lesser degree on delivery schedules, permitted flow fluctuations, topographic features of the right-of-way, and the physical properties of the product. These usually vary from field to field and depend on well-stream pressure, temperature, and specific gravity as well as the exact chemical composition. There are many combinations of diameter and pressure that can provide the needed flow rate. Often there is a trade-off between an increased number of intermediate pressure booster stations and a larger diameter pipe. However, the practice of limiting pump or compressor stations to the end of an offshore pipeline removes some of this flexibility.

Although marine pipelines are expensive to construct, the practice generally has been to build separate pipelines for oil and gas rather than to use a mixed phase pipeline. The reasons are the difficulty of pumping (or compressing) a mixture of oil and gas and the more complicated control and separation equipment. Consequently the gas and oil are usually separated at the platform and transported onshore in separately designed pipelines. This procedure obviously depends to a degree on the relative and absolute quantities of oil and gas and the costs of the pipeline systems. In some cases, for instance, oil and gas are separated at the platform, pumped or compressed to high pressure, and then remixed for transport to shore in a single pipeline.

After the pipeline's diameter and operating pressure have been established, all other components of the system are designed within the previously mentioned code requirements, which are based primarily on diameter and pressure. For example, the pipe wall thickness for liquid flows is designed according to internal pressure, external pressure, and combined stresses as required by 49 C.F.R. §195. The hoop stress in the pipe is of course directly a function of the pressure and diameter of the pipe. Besides the hoop stresses, however, there are longitudinal, shear, bearing, and expansion stresses caused by dynamic effects, as well as weight effects. Dynamic effects are those due to impact, wind, earthquakes, vibration, subsidence or wave and current action and have to be included in designing for allowable stress levels. Live weight loads such as the weight of liquid being transported and dead loads such as the pipe weight, coatings, and backfill are also included in calculations. Valves are designed according to maximum operation pressure. Pump and compressor stations are designed and spaced in accordance with design pressure, pipe grade, wall thickness, diameter, and the topographic features of the right-of-way.

3.2.2 Route Selection

Route selection is an essential part of the planning and design process and relates directly to the material concerned in this report. Several aspects of route selection have already been mentioned, including the fact that it involves a series of progressively more detailed steps during the planning and design stage. That is, it is an evolutionary process. Although many of the basics in route selection are the same, it is clearly carried out in a case-by-case manner. Therefore, due to specific onshore or offshore features, questions of right-of-way ownership (particularly at landfall), and many other site specific problems, care should be used in making general conclusions about likely pipeline routes.

Without question, the primary industrial criterion in selection of a pipeline route is minimization of the total life cycle costs of the system. Because offshore pipeline costs are at least twice those of onshore pipelines, it is natural to assume that route selection will be such as to minimize the distance to landfall. This also has the advantage of minimizing exposure of the pipeline to offshore hazards. Several factors may invalidate this conclusion, however. For example, higher offshore construction costs may not be controlling, if onshore considerations regarding wetlands, swamps, or other ecological and cultural systems significantly increase onshore construction costs. In addition, increases in construction time add tremendously to the costs of construction. Thus areas in which regulatory procedures may be vague or time-consuming, or in which legal action is likely, are often avoided, even if it results in an increase in offshore pipeline length.

Before the confirmation of a commercial discovery, the initial planning for the pipeline route is carried out by identifying broad, direct paths that connect the offshore lease to a suitable landfall site. Selection of a suitable landfall is probably the most difficult aspect of this task. It usually is based on a general study of the area, including ecological, environmental and cultural features, as well as the desired destination of the product. Given the endpoints, initial route selection is based primarily on topographic feasibility, and may then be used to make first estimates of pipelengths in the design process. Other considerations that will refine and likely redefine the possible routes are given by Gowen et al. (1980) as: (a) A landfall site which is compatible with pipeline construction and maintenance, and with restoration and maintenance of the shoreline. Some areas that may be avoided are congested coastal areas, wildlife preserves, wilderness areas and other known sensitive areas. (b) Suitable construction conditions along the pipe route. Canyons, boulder areas, rock outcroppings, unstable areas, etc., would usually be avoided. (c) The capability to provide pipeline protection from outside forces and influences. Ship anchorages and other areas with high potential for damage to a pipeline are avoided. (d) The limiting of the effect of the pipeline on sensitive environments. Environmentally sensitive areas such as oyster beds are avoided.

After confirmation of a commercial discovery, the preliminary routes delineated for transporting the oil and gas are evaluated in detail, considering all engineering and construction factors as well as potential environmental disturbances. At this time detailed topographic and geophysical route surveys are carried out to aid in route selection and to meet permit

application requirements. The detailed route surveys usually include a general survey of a strip along the centerline of the route and the area between two offset lines, each about one thousand feet either side of the centerline. A bottom profile from a fathometer is obtained along the centerline and both offset lines. Miniseismic records with a penetration of 25 to 50 feet give a sub-bottom profile, while a magnetometer is used to identify other pipelines, cables, wrecks, etc., that may lie along the route. The information gained from all the surveys is then correlated and studied to develop a hazard survey. In addition, the data is examined by an archeologist for archeological significance (Gowen et al., 1980).

During actual construction of the offshore pipeline, surveys are carried out to ascertain the final location of the finished pipeline.

For onshore locations, the process of route selection starts with a broad mapping of a feasible corridor which is as short as possible from the origin to the destination. A general study is made of the the topographical and cultural features of the corridor, and particular note is taken of important "control points" (NERBC, 1976). Control points such as river crossings, existing rights-of-way, etc., are considered as places to be either definitely avoided or definitely included in the final route selection.

A preliminary layout is selected following consultation of local town or city assessor maps, soil conservation maps, town or city zoning maps, property plans, roadway layout plans, and maps prepared by federal, regional, state or local agencies which detail special land uses and development constraints (NERBC, 1976). Aerial photography of areas about three miles wide along the proposed route can provide very useful detailed information. The photographs show the layout of the land in sufficient detail to select routes that avoid or minimize interference with buildings, orchards, and other improvements likely to be of special interest to landowners (Petroleum Extension Service, 1973). On-site surveys are made of the route to determine the location of buildings and property lines and in environmentally sensitive areas to assess potential impacts.

There are six factors that are usually considered when selecting a right-of-way (NERBC, 1976):

(1) Topography. Topography is very important for routing liquid pipelines. Flat or gently sloping areas are preferred because construction and maintenance costs are less and there is less pumping loss. A slope of 45 degrees is considered steep. Natural gas pipelines are less affected by topography.

(2) Geology and Soils. Construction in soils with more that 10 percent consolidated rock is undesirable and such areas should be avoided if possible. Soils that either erode or compact readily are difficult in construction. Well-drained, loamy soils with the water table at least five feet below the surface are considered ideal.

(3) Water Bodies. Lakes and ponds are avoided if at all possible. Crossing points for rivers are carefully selected by considering the approach to the river and the river width and depth at that location.

(4) Land Use. If possible heavily populated and intensively cultivated land areas are bypassed. Open land is preferred to forested land because it takes less right-of-way preparation. Often land areas are already restricted

to other purposes such as wilderness or military use and are not always available to pipeline passage.

(5) Environmental Concerns. Sensitive areas are avoided if possible, and attempts should be made to minimize the length of pipe in wetlands, sensitive coastal zones, and nesting or spawning areas.

(6) Existing Rights-of-Way. Existing roads, railroads, electric transmission lines, and other pipelines are paralleled whenever possible.

After identifying a possible route, the right-of-way for the pipeline has to be secured by permit or purchase. The pipeline companies enter into agreements with landowners and public agencies to allow construction, operation, and maintenance of the pipeline. Sometimes the company is required to purchase the land. Permits must be obtained for crossing railroads, highways, roads, streets, rivers, canals, drainage ditches, and various other facilities. Detailed plans for such crossings are submitted with an application for the permit. Acquiring all the required right-of-way permits, negotiating agreements, and making land purchases is a major task associated with route selection.

3.3 CONSTRUCTION METHODS

Construction of the pipeline is usually the most damaging activity associated with the presence and operation of a pipeline system. The cost and hence the route of the pipeline will vary with construction methods. Thus, an overview of the methods used in pipeline construction is provided here.

Virtually all oil and gas pipelines are constructed of high quality steel pipe. The pipe is manufactured in either standard lengths of 40 feet (particularly for offshore lay barge operations) or random lengths of 30-60 feet and are inspected both at the factory and during various phases of the installation. Pipeline construction basically consists of various methods of welding the pipe sections together and placing the pipe along the route. Due to difficulty in transporting pipe lengths over 40-60 feet, the usual practice is to carry out the welding process somewhere in the field. In addition to welding, the pipe is usually coated with at least one protective coating. This is an asphalt-like mastic compound which serves primarily to protect against corrosion. When needed, offshore pipe is given a second coating of concrete to provide both additional weight for secure anchoring and additional mechanical protection. The standard procedure is to girth-butt weld the sections of pipe together at some point during the pipelaying operation. These welds are inspected to ensure that they meet the quality standards set in the API publication API STD 1104 "Standards for Welding Pipelines and Related Facilities" (which is incorporated by reference into 49 C.F.R. §§ 192 and 195). If the pipe coating was applied before welding, then additional coatings must be applied to the weld joints before the pipe is laid. The techniques and some additional description of pipeline construction for various construction methods are given below.

3.3.1 Offshore Installation

Marine pipeline construction usually employs one of three basic methods of pipelaying. These are the lay barge or "stovepipe" technique, the reel barge technique, and the pull technique. Depending on sea-bottom conditions the pipeline may either be simply laid on the bottom or it may be buried in a

trench. The trench can be left open or backfilled. Current Minerals Management Service (MMS) OCS regulations for the Gulf of Mexico require burial in water depths of less than 200 feet. Burial in water depths greater than that may still be preferred (or required) to protect the pipeline from damage by anchors, trawling gear, sediment movement, geologic hazards, or for other reasons.

Because all offshore pipelaying operations require ships and/or barges, the operation may be suspended for weather or other reasons. When this occurs, the pipeline is usually capped and lowered to the bottom. Retrieval of the pipe end and subsequent connection with the next pipe section, as well as handling of other in-place pipe connections and repair work, requires special operating techniques, particularly in deep water. In rare cases the pipe may buckle or the pipe "string" may be lost without a cap. Recovery of a flooded pipe string, especially in deep water, can be particularly costly and difficult.

3.3.1.1 Laying the Pipeline

The lay barge or "stovepipe" technique is the most common of three basic methods of offshore marine pipelaying in shallow and moderate water depths. A conventional large, flat-bottomed vessel about 420 feet long and 120 feet wide is used as the lay barge. Coated pipe sections are delivered to the lay barge by supply barges or ships and stacked ready for use. When needed, the pipe sections are moved to a station near the bow of the barge, inspected, prepared and then positioned for entry into the lay system. The pipe section must be joined (welded) to the pipeline which is being laid from the stern of the barge. Along the length of the barge there are separate work stations where the pipe is welded, x-rayed, cleaned, coated, and launched. After the operation is completed at each of the different stations, the lay barge moves forward one pipelength and a new section enters the lay system.

The continuous string of connected pipe sections is launched from the stern of the barge over an inclined or curved ramp (called a stinger) extending out from the barge. The stinger allows for a smooth transition in curvature of the pipeline from the near-horizontal direction of the work stations on the barge to the incline of the sagbend towards the ocean floor. The pipeline is held in tension by tensioners on the barge, and the combination of stinger and tensioners is designed to prevent excessive stresses (buckling) in the pipeline being laid.

The barge is held in position by a set of mooring lines attached to large anchors. To move forward, and so launch a section of pipe, the barge winches in the mooring lines to allow repositioning. At periodic intervals the anchors themselves have to be reset by tugboats.

The conventional flat-bottomed lay barges are most commonly used for offshore pipelaying because they are simple and economical, provide ample space for stored pipe sections, experience low drag and mooring line forces, and their shallow draft permits operation close inshore as well as offshore. The barges are, however, sensitive to wave climate and may shut down pipelaying operations in six- to fourteen-foot waves (NERBC, 1976). They also require the support of tugboats for repositioning of anchors. There is a limit to the water depth for their pipelaying, set in part by the tensioners

on the barge (Hughes, 1980). Alternatives to the conventional lay barge include semi-submersible lay barges and ship-shape vessels, both of which are better suited to deep-water operations. The semi-submersible lay barge has large pontoons and columns which are flooded and submerged during operation and which provide greater stability in deeper and rougher seas. The improved stability allows pipelaying operations to continue for large diameter pipelines for a sea state of up to 30 feet. The semi-submersible barges do not have the storage space of conventional barges, though, and therefore depend on the ability of tugboats and supply ships to operate in rough seas. Ship-shape vessels are not often used for pipelaying operations because the high draft and freeboard increase the mooring forces and limit the minimum working water depth. However, they are often self-propelled and not as dependent on tugboats.

For the reel barge technique a number of pipe sections are welded together, tested, and given a protective coating at a shore base, then wound onto a large diameter reel on the barge. The barge is towed to site, where the end of the previously laid pipeline is picked up from the ocean floor and joined to the pipe coil on the reel. The barge is towed forward, the new section of pipe is spooled off the reel, straightened, and launched. There are special rollers to facilitate the straightening of the pipe, and the launching ramp is similar to the stinger described earlier. The length of coil on a reel is dependent on the reel size and the diameter of the pipe and may vary from 2 to over 30 miles. After a coil of pipe is laid, the pipe-end is capped and lowered to the ocean floor. The barge returns to shore to wind a new length of pipe on to the reel.

The reel barge technique facilitates fast installation of the pipeline. In particular, the time spent on site reeling out the new section of pipe is minimized, making it easier to plan operating times in heavy ship-traffic zones or in variable weather conditions. In addition, the shore-based activity is cheaper to sustain than if it were vessel-bound and required supply ships. However, the reel method is limited to smaller diameter pipelines because of the bending stresses when reeling and because of limited reel size. Pipeline diameters of 12 inches or less are usual, while 16 inches is possible, and new designs are planned for 24-inch diameter pipelines (Gowen et al., 1980).

Because of the reeling and straightening operation, it is not feasible to provide a concrete coating on the pipe to provide mechanical protection and extra weight. Extra weight for stability must be obtained by increasing the pipe wall thickness, which has certain advantages for strength and pipeline life, but increases the cost.

The pull technique is an extension of a technique developed for landfall zones which has been recently applied to offshore, deeper locations. For the pull technique, pipe strings are assembled at one location and towed to site for installation. In the bottom-pull method the pipe is made up at a shore base location, then dragged along (or floated just above) the ocean floor by tugs, barges or winches to the installation site. The pipe strings are limited in length to about 2-4 miles because of the frictional drag (NERBC, 1976). The technique is cheaper than the lay barge operation and is not as sensitive to bad weather, but requires careful selection of a towing route in order to avoid dangerous topography and obstructions that may damage the

pipeline. In addition, the pipe strings have to be tied into existing lengths of pipeline. It is possible to join strings by underwater tie-ins, but that is expensive. A more recent variation of the technique, known as the floating string method or the towing, tie-in, tension method, R.A.T. (see Funge et al., 1977) involves attaching flotation devices to long pipe strings assembled onshore and towing the strings to site. The pipe string may be joined to the existing pipe-end on a lay barge, where the string passes over the barge and is lowered to the seabed with a conventional stinger and tensioner system. The floating string method requires calm seas.

The factors involved in the choice of a particular pipelaying technique for offshore installation are a complicated mix based on economics, site constraints, environmental constraints, pipe size, and available equipment. In particular, the technique likely to be used in North Carolina coastal waters is difficult to predict. Here pipe laying activity will be in deeper water than normally experienced, but certainly within the capability of most offshore corporations. The wind and wave climate will be more severe than the Gulf of Mexico, but less severe than the North Sea. The use of a modified form of lay barge or semi-submersible is considered most likely. The technique will also depend to some extent on pipe diameters, which in turn depend on anticipated production rates from the entire field.

3.3.1.2 Trenching and Burial

The question of burial of offshore pipelines has received considerable attention. MMS's OCS regulations in the Gulf require pipeline burial for main pipelines in less than 200 feet of water. The pipelines must be buried to a depth suitable for adequate protection from water currents, sand waves, storm scour, commercial fishing trawl gear, and other factors as determined on a case-by-case basis. Generally, it is common industry practice in water depths less than 200 feet to bury pipelines at least 3 feet below the existing seabed (Golden et al., 1980).

There are widely held views that such burial is not necessary, and in some cases harmful. The American Petroleum Institute recommends that the pipeline not be entrenched unless there are waves, currents, marine activities, or other factors that would be detrimental to the exposed pipeline (API, RP 1111). A major concern has been the snagging of commercial fishing equipment on exposed pipelines. However, recent studies have shown that heavy trawl doors, such as those used in commercial fishing off North Carolina, tend to snag less on exposed pipelines than on pipelines entrenched and not adequately backfilled (NERBC, 1976). In any case all valves, taps, etc., should be buried.

Pipeline burial is carried out by excavating a trench into which the pipeline can be lowered. The trench may be dug either before the pipeline is laid (pre-trenching) or after it has been placed on the seabed (post-trenching). The depth of the trench may vary from three feet in deep water to 10 to 12 feet near the landfall (Rooney-Char and Ayres, 1978). The actual depth to which a pipeline must be buried is determined on a case-by-case basis.

After laying the pipeline in the trench, burial may be accomplished by active backfilling or may be left to the natural processes of current and

wave-induced sediment motion (natural backfilling). Natural backfilling is the most common choice in sand and clay soils where sediment transport readily takes place. There are cases, however, where natural backfilling has been prescribed but on later inspection has been found not to have taken place, for example in the case of the Ekofisk to Emden line in the North Sea (Gowen et al., 1980). This has raised the question of the utility of trenching offshore, and in a study by Shell Expro (Gowen et al., 1980) it was concluded that: (1) bottom currents are insufficient in deep water to provide sediment transport for natural burial; (2) present coating technology is such that trawl doors will not do significant damage to a concrete coated pipeline; (3) trawl doors are more likely to be damaged when dragged across an unfilled trench than an unburied pipeline; and (4) burial does not protect a pipeline from drilling rig or tanker anchors. These conclusions are not universally accepted, and there is a debate about the utility of trenching in deeper waters, although there is agreement on the necessity for burial in more unstable nearshore areas, and for burial of all valves, taps and other projections.

There are four major trenching techniques in common use. These are jetting, mechanical cutting, fluidization, and plowing. Each is briefly described below.

The most common method of post-trenching is by jetting. A jet sled travels along the pipeline and uses high pressure water jets to blow a trench in the sediment on the seabed. The sediment is sucked up by pipes and discharged to the side of the trench. As the jet sled moves forward, the pipeline settles into the trench and is partially buried by reworked sediment. Along the Forties Field pipeline in the North Sea, the average jet sled rate was about 0.6 miles per day in clay and 1.8 miles per day in sand and silt (Gowen et al., 1980). One pass was needed to trench to a depth of 6 feet in clay, but two passes were sometimes required in sand and silt.

For the method of mechanical cutting, a machine with rotating cutterheads is drawn along the pipeline to cut through the sediment. These machines can dig trenches up to 8 feet deep and have been reported to travel at 296-755 feet per hour in sand and 427-1640 feet per hour in clay (Gowen et al., 1980).

Fluidization is a technique that is designed for relatively noncohesive sediments, such as sand, where conventional trenching techniques are ineffective. The method involves forcing a large volume of water into the soil surrounding the pipe, thus fluidizing the soil and allowing the pipe to settle. The technique is such that the pipeline is automatically buried, but the method is only effective in sandy soil.

Plowing is a relatively new technique for deep water applications and involves drawing a simple plow along the trenching track. It may be considered as a pre- or post-trenching technique and is best suited to soils of soft to medium clay (Golden et al., 1980).

The trenching machines described above do not work well for rocky or stony seabeds. Where these areas cannot be avoided, there are four alternatives available: (1) conventional dredging using rock buckets for the softer and fractured rocks such as chalk, shales, and mudstones in water depths of less than 100 feet; (2) drilling and blasting from surface craft,

often preceding dredging in harder rock areas, but limited to 88-131 feet in depth; (3) seabed blasting with charges placed on the seabed by divers; and (4) anchoring. Anchoring is used where trenching and burial are not possible, but the pipeline needs to be protected from physical influences that would tend to move it. The most common method of anchoring is the use of concrete coating on the pipe. For reel barges this is not possible, and here and in cases where additional stability is needed, large concrete weights or mechanical anchors are used (Golden et al., 1980).

3.3.1.3 Deep Water Operations

There are some aspects of pipeline installation that are more difficult to carry out in deeper water. Pipeline abandonment and retrieval, the making of pipeline connections and tie-ins, and possible buckling and associated repairs become major concerns in deep water operations.

Pipelaying operations are sensitive to weather conditions, and when conditions are such that the operations must be stopped, the pipeline is capped and lowered to the sea floor to prevent damage to the pipeline and stinger. The pipe end is marked by a marker buoy. When weather permits, the pipe is retrieved and pipelaying continues, or the operator may choose to begin laying a second pipeline near the end of the first and connect them later (Golden et al., 1980).

Connections and tie-ins of pipelines are also necessary when using a reel barge, connecting pipelines to platform risers, or on occasions when a tight construction schedule calls for two pipeline crews to work simultaneously from either terminal of the pipeline. The principal method of connecting is to bring the two pipeline ends to the surface and carry out the welding on a barge. The pipeline is then lowered back down to the seabed while the barge travels transversely to allow for the geometry.

A method that has been increasingly used for risers and tie-ins which may also be used for pipeline coupling is the underwater mechanical connector. The flange type coupler involves fitting both ends with flanges, aligning, and connecting in place. Mechanical coupling may also be achieved by use of a sleeve that fits over the pipe ends and is locked and sealed. Hyperbaric welding, where the two pipes are welded together underwater in a dry habitat, has also been used; this technique has been applied in the Gulf in depths of 330 feet, for example (Golden et al., 1980).

Buckling of the pipeline most commonly occurs in the sag bend between the barge and the seabed. It may be initiated by anchor slippage or breakage, loss of pipe tension, damage to the stinger, loss of stinger control, or errors in moving the barge ahead. The extent of damage may be such as to only damage the coating (which may be repaired by divers), or it may cause major disfunction or breakage of the pipeline (NERBC, 1976). Repair methods will depend on the location and nature of the buckle. Sometimes the damaged portion of pipeline can be drawn back onto the ramp by backing up the barge. For ruptured pipelines, repair is more difficult and expensive because the pipeline floods and becomes too heavy to raise to the surface. Underwater repairs are first needed to cap the pipe off before reconnections can take place.

3.3.2 Landfall Installation

The landfall is defined as that portion of the pipeline route shoreward of the point where standard marine pipelaying techniques and equipment operate, to an onshore location where standard land pipelaying operations can begin. Crossing this region requires special techniques that vary with the characteristics of the coast. Compared to marine pipelaying activities, particularly in deep water, operations in the landfall region are usually technically less complicated. However, this usually is a region of high environmental and/or cultural sensitivity. Thus operations in this region can have a substantial impact on pipeline costs and impacts.

There are three common techniques used in construction of a pipeline in the landfall region. These are the pull method, the push method, and the flotation technique. The method that will be utilized depends on pipe diameter, topography and geology of the sea bottom, and on the soil conditions of the shoreline and surrounding land (Rooney-Char and Ayres, 1978).

3.3.2.1 Pull Technique

The pull technique is the basic installation method for firm shorelines with sufficient bearing capacity to support land excavation equipment, large winches, and heavy welding and coating equipment (Gowen and Goetz, 1981). There are two variations to the pull technique: the barge-based pull and the shore-based pull. In the barge-based pull, pipe strings are made up at the shore work area and pulled offshore by barge-mounted winches. The barges are anchored offshore and as each pipe length is pulled, a new one is welded on at the shore base. For the shore-based pull technique, the roles are reversed and the pipeline is pulled from barge to shoreline with the welding and coating taking place on the barge. It is anticipated that the pull technique would be used at most potential landfall locations in North Carolina.

The pipeline is usually placed in a trench which is excavated from the shore out to where the lay barge can operate. Sheet piling may be used to allow the excavation of a narrow, stable trench and to minimize the impact and right-of-way width. Especially deep burial may be called for on sandy beaches to protect the pipeline from erosion. Nearshore trenches are either pre-excavated with barge-mounted clamshell or dragline dredges, or the pipeline may be buried after installation by trenching machines. In very shallow water, excavation may take place from equipment mounted on temporary platforms or jetties.

The sediment or spoil from trenching may be stored on the beach, used for construction of temporary facilities in the surf zone or landward of the dunes, or deposited a short distance offshore for return by natural processes (Gowen and Goetz, 1981). During construction, spoil piles onshore are generally stabilized with netting, vegetation, fences, or thatching to reduce the effects of wind erosion and water runoff.

The degree of restoration for a trenched area depends on several factors, including the environmental sensitivity of the affected coastal systems, the present and future use of the landfall area and associated right-of-way, and government regulations, ordinances and requirements. In the foreshore/beach zone, the trench is usually refilled with original material. With the sheet

piling removed and the beach graded to original contours, aesthetic recovery is quick, but the beach may be more vulnerable to wave erosion until sediment transport by natural processes reaches an equilibrium. For cobble or shingle beaches, clean gravel or armorstone is sometimes used with an upper covering of original or similar material (Gowen and Goetz, 1981).

Special care is usually taken with the storage of the upper vegetative layer on dunes so that it can be used in restoration. One of the primary concerns with dune restoration is to ensure the dune's return to its natural protective function in sheltering backdune wetlands and other environments from wave attack and salt water inundation. In the backdune areas, the trench is refilled with original material, graded, fertilized, and replanted. Water drainage patterns are restored to the greatest extent possible to prevent washouts and erosion (Gowen and Goetz, 1981).

3.3.2.2 Push Method

The push method is suited to wetlands with relatively firm and stable soils that can support light traffic. A pipe welding station is set up on land or on a stationary lay barge. A new section of concrete coated pipe is welded on, floats are attached, and the pipeline is pushed into a prepared ditch. After the entire length is floated into position this way, the floats are cut away and the line is allowed to sink to the bottom of the ditch. Refilling of the push ditch is usually required by regulatory agencies or landowners (Gowen and Goetz, 1981).

The pipe ditch may be excavated by a marshbuggy-mounted clamshell or dragline dredge. If the soil is not too firm, though, the marshbuggy may leave track marks on the marsh surface that may alter marsh drainage. The ditch is usually 4-6 feet wide and about 8 feet deep, with the spoil piled on both sides ready for refilling (Gowen and Goetz, 1981).

3.3.2.3 Flotation

The flotation method is suited to soft, muddy soils which cannot support any traffic. A flotation canal, wide enough to accommodate small lay barges, is dug by barge-mounted bucket dredges. The pipe ditch is then excavated in the bottom of the 40- to 50-foot wide and 6-foot deep canal, such that the pipeline will end up about 10-12 feet below the water surface (Gowen and Goetz, 1981). In some cases a jet barge may be used instead, to jet water around the pipe to form a trench for the pipe to settle into (Golden et al., 1980). The highly fluid spoil is spread to either side to form low flat levees. The total right-of-way width for flotation installation is about 300 feet (Gowen and Goetz, 1981). The pipeline is laid from the lay barge as it moves up the canal.

Special considerations are needed for wetland restoration where strict requirements or specifications are in effect. Even where restoration is attempted, total return of aesthetic quality of the system may not be expected. The primary concern is to minimize the environmental impact of construction on the system's function (Gowen and Goetz, 1981). The spoil from the canal excavation is usually not sufficient to completely refill the canal, and additional material may be required from nearby open water or lakes. Continuous levees may need to be breached to prevent alteration of the

wetland's natural drainage pattern, but decisions are usually made on a case-by-case basis. Push ditches, however, are easier to restore than the flotation canals, and regrowth of natural vegetation will cover all visual evidence of the ditch.

Landowners and government agencies may require flotation canals and push ditches to be blocked by plugs or dams where they cross major waterways. The blockage may be needed to prevent boat traffic on the canal and may be used to prevent alteration of the natural drainage pattern and to prevent salt water intrusion. Revegetation of restored wetlands is not commonly attempted because indigenous systems usually take over.

3.3.3 Onshore Installation

Pipeline construction on relatively firm, dry land involves a sequence of steps that starts with the clearing of the right-of-way and continues through cleanup and restoration. The crews and equipment that perform these steps make up a single construction unit known as a spread. The spread is stretched out along the right-of-way and typically advances at speeds of 1-3 miles per day (Petroleum Extension Service, 1973). Obstacles such as river, road, and railroad crossings require additional specialized construction units (NERBC, 1976), and different equipment and techniques may be needed for swamps or wet and unstable ground conditions.

3.3.3.1 The Pipeline Spread

Following the surveying and marking of the right-of-way, there are eight major sequential steps involved in laying a large diameter pipe. These steps are: (1) clearing and grading of the right-of-way; (2) stringing of the pipe along the pipeline route; (3) trenching; (4) bending of the pipes to match the ditch contour; (5) welding and inspection of the pipe; (6) pipe coating; (7) lowering of the pipeline into the ditch and backfilling; and (8) clean-up and restoration of the right-of-way (Golden et al., 1980).

To provide a flat open space 50 to 100 feet wide for subsequent construction activities, the right-of-way is first cleared of vegetation and other obstacles and the ground surface graded sufficiently to permit operation of vehicles and equipment (Petroleum Extension Service, 1973; NERBC, 1976). Clearing may be done with power saws, bulldozers, timber-blade attachments, and/or hand labor, depending on the type of vegetation, the topography, and the ability of the area to support heavy equipment. On steep, rocky hillsides grading may be a major operation requiring blasting, earthmoving and soil stabilization (Petroleum Extension Service, 1973).

Sections of line pipe and the various fittings, valves, and coatings that are to be used must be transported to the site and strung out along one side of the right-of-way. This task is usually performed by trucks which are loaded and unloaded by tractors or trucks fitted with side booms or various other crane-like devices (Petroleum Extension Service, 1973). Trucks can usually proceed from a highway onto the right-of-way, but tow tractors may be needed to assist trucks across difficult terrain, and in very rough areas helicopters may be used. With all the handling, care must be given to proper protection of the pipe. Temporary storage at intermediate locations is sometimes necessary in the process of stringing the pipeline.

Pipe sections may be strung before or after the ditch has been dug. As a general rule, completed ditches are open for a minimum period of time before the pipe is lowered in. For this reason, stringing usually precedes ditching. When blasting is required to make the ditch, however, stringing will be delayed to avoid possible damage to the pipe (Petroleum Extension Service, 1973).

A trench or ditch must be excavated to receive the pipeline, and the trench width is usually 12 inches greater than the pipe diameter. The trench is excavated to a depth such that the soil cover on the pipeline will meet federal regulations. The regulations require a minimum soil cover of 18 to 36 inches, depending on the type of soil and areas crossed by the pipeline (NERBC, 1976). However, depths of soil cover may range up to 60 inches, depending on company practice.

The trenching method will depend on soil type. For well-drained and rock-free soil, a trenching machine can be used. Where the soil conditions are unusually rough, a backhoe may be necessary. In rocky soils, rippers are used, or when necessary, blasting may be employed to clean a trench. For wetlands and areas with high water tables, draglines and clamshells are used to excavate the trench (NERBC, 1976).

After excavation, it may be necessary to bend the pipes strung out along the right-of-way so as to match ditch curves and contours caused by changes in direction or elevation. Individual pipe sections are placed in a hydraulic bending machine fitted with semicircular shoes that hold the pipe as pressure is exerted to bend the pipe. In general, the extent to which a pipe can be bent varies with its diameter. A 36-inch diameter pipe can be bent 1.5 degrees for every 36 inches of pipe length; a 24-inch diameter pipeline, 1.5 degrees for every 24 inches; and so on (NERBC, 1976). Bending machines are heavy pieces of equipment and are usually mounted on tracks or slides. They can be hauled by truck or pulled along the right-of-way by tow tractors (Petroleum Extension Service, 1973).

Welding is one of the most important steps in pipeline construction and requires highly trained specialists. Before being permitted to work on a pipeline project, a welder must have passed qualification procedures described in 49 C.F.R. §§192.227 and 195.222. Pipe ends are first thoroughly cleaned of rust, dirt, and coating with brushes and grinders (NERBC, 1976). Pipe ends are lined up and clamped together to provide uniform spacing between the ends. The spacing varies according to welding methods and may range from 0 to 1/16 inch (Petroleum Extension Service, 1973). Tractors with side booms are used to support the pipe until a partial weld is made of sufficient strength to permit placing the pipe on blocks. The tractors then move on to the next section of pipe. Once on wooden supports or skids, the clamps are removed and the weld completed.

Once the welds are completed, they are tested nondestructively for compliance with weld standards described in DOT regulations. The common nondestructive methods are visual inspection, radiography (x-ray), ultrasonic, and magnetic particle techniques (Golden et al., 1980). Government regulations often require nondestructive testing of a least 10% of welds in open country, and 100% of welds at certain locations such as railroad and

river crossings and highway rights-of-way. Industry practice may exceed these minimum requirements.

Coatings to protect against corrosion are almost universally regarded as essential for trunk pipelines. Field coating of the bare pipe usually involves two steps. After the welding is completed, the pipe is cleaned and primed. Use is often made of a single cleaning unit, containing both a rotating cleaning head fitted with various scrapers, brushes and discs, and a priming attachment, that advances along the pipe under its own power. Once the primer has dried, a second unit applies the main protective coating and wrapping. Several types of coatings are used; in one common sequence, the pipe is coated with an enamel made of coal tar or asphalt with various fillers and additives. An attached wrapping head then wraps the pipeline with a reinforcing fabric such as fiber glass which is imbedded into the wet enamel, and a layer of shielding material such as asbestos felt and paper is used to provide a final layer of protection.

If the coatings have been applied to each section of pipeline at a central preparation yard before stringing and welding, then only the exposed end sections and weld area need to be coated on site.

Where the pipeline trench has an irregular or rocky bottom, padding materials such as sand, soil or gravel may be placed in the trench to protect the pipe and its coating (NERBC, 1976). The pipe string is lowered into the trench by a series of side-boom tractors equipped with either rubber tire cradles or slings and belts. Special care must be taken to not injure the protective coating and to also provide sufficient support to prevent buckling or other damage (Petroleum Extension Service, 1973). Additional padding may be placed on top of the lowered pipeline if the excavated material for backfill is rocky. The bulldozer is the most popular machine for backfilling, although motor graders, angle dozers, and crawler-mounted, side-pull backfillers are also used to move excavated dirt back to the ditch (Golden et al., 1980). Compaction of the loose backfill is often accomplished by driving a heavy crawler-type tractor over the filled trench.

After backfilling and compaction, the right-of-way is cleared of all construction materials and debris. Disc harrows or other equipment may be used to break up clods and smooth rough surfaces. Runoff diversions and various stabilizing materials including vegetation may be employed to limit erosion. Steep embankments may require terracing. As a last step, markers are installed to indicate pipeline locations.

3.3.3.2 River and Stream Crossings

River crossings are important because of the economical, social, and environmental implications of such crossings. They have the highest per unit length cost of most pipeline construction (Petroleum Extension Service, 1973). To a large extent, the choice of pipeline route can be affected by the locations of favorable or unfavorable crossing sites, as measured from different points of view (Golden et al., 1980). Procedures used for the crossings vary with the characteristics of the waterway and the preference of the construction company contracted for a job.

There are a variety of methods available for river crossings, most of which involve burial in the river bottom sediment. Burial must be deep enough to protect the pipeline from sediment scour and other hazards. On small streams, the ditch may be excavated with draglines operated from the stream bank. On larger rivers it is usually necessary to float the excavation equipment on a barge (NERBC, 1976).

In the "bottom pull" method, pipe strings of several pipe lengths each are made up on one side of the river and then pulled into the ditch across the river by crawler tractor or winch. New pipe sections are strung and welded on as the pull advances across the river. Sometimes a dredge has to be located midstream so as to keep the trench clear of sediment and silt (Golden et al., 1980). To keep the pipeline down usually requires some means of providing negative buoyancy such as concrete coating, bolt-on river weights, saddle weights, or anchors (NERBC, 1976).

In the "floating bridge" method, a pipestring equal in length to the river width is made up on one side of the waterway. It is placed on a set of pontoons in the river and floated into position over the prepared ditch. The string is lowered into the trench and then welded to the pipe ends at each side of the river (NERBC, 1976). On very large rivers, a small lay barge may be used whereby the pipeline is welded on the barge and then laid in the trench from a ramp as the barge advances across the river.

Burial of the pipeline might be by backfilling, jetting, or silting in. On wide rivers, the spoil from excavation is dumped on the upstream side of the ditch, and after the pipe is laid some effort is made to backfill using a dragline. If the river is not very wide, then the draglines will operate from the banks, store the spoil on land, and backfill from the spoil piles.

If a pipeline is to be buried at a non-navigable river crossing, a diversion dam technique may be employed. A partial diversion dam is built in the river, starting from one bank. The dredging of the trench takes place on the protected side of the dam, but because the dam only partially blocks the river, the water continues to flow downstream. Construction progresses across the river with the spoil continually being placed ahead of the pipelaying operation and removed from the rear (Golden et al., 1980).

Where an underwater crossing is not possible, an overhead crossing may be used. The pipeline is supported either by a newly constructed bridge, such as a suspension bridge, or by an existing structure, such as a railroad bridge. This technique has the advantage of avoiding bends in the pipe, burial of the pipe, and sometimes difficult diversion of the water flow during construction (Petroleum Extension Service, 1973). However, the technique has difficulties of its own, including engineering problems of pipe and support strength for wind, temperature, and weight loadings affecting pipe vibrations, and exposure to high water flooding, floating debris, and other environmental hazards. For these reasons and because the pipe may interfere with water flows, this technique for river crossing is not favored by many pipeline operators (Golden et al., 1980).

One of the most promising new techniques for river crossing is that of directionally controlled, horizontal drilling. The technique involves a remotely controlled cutting head that passes well beneath the stream bed. A

cutting head is mounted on the lead end of an instrumented section carrying a hydraulic motor and a positive displacement pump. The cutting head is rotated by the hydraulic motor, and it cuts a tunnel underneath the river bed, starting from one shoreline. A tunnel casing is pulled into the bore hole just behind the cutting head. The tunnel direction is controlled by an operator at the shore who is fed directional and speed information from the instruments near the motor. The rig can be set at any angle from 0 to 30 degrees to the horizontal. There are two mud handling techniques. With one system, the mud and cutting fluid are pumped by the positive displacement pump to a mud treatment system for separation of the solids before the fluid is circulated back to the cutting head. Alternatively, a separate system may pump the mud into the gap between the wall of the bore hole and the tunnel casing to lubricate and facilitate the advance of the casing (Golden et al., 1980).

The directionally controlled tunneling method has been used to install a 24-inch diameter pipeline under Greens Bayou, a few miles east of Houston. The 751-foot long tunnel carried the pipeline 23 feet under the bottom of the bayou, well below the working depth range of most excavating equipment (Congram, 1978). The technique is attractive to pipeline builders, regulators and environmentalists because it is an apparently cheaper, more environmentally benign, and quicker method of making river crossings. The advantages are numerous, including minimal ecological damage by not disturbing the river or river bottom, no interruption of surface traffic, deeper burial than by excavation with no problem of backfill or erosion, and the need for fewer permits. It is a relatively new technique, though, and limitations have not yet been established for distance and depth (Golden et al., 1980). However, the technique has potential applications at landfalls and road and railroad crossings, as well as river crossings.

Initial hydrostatic testing of the pipeline strings is sometimes advisable before the pipeline is laid at a river crossing, because of the difficulty and cost of repair once it is in place. After the pipeline has been laid, it will be tested again to meet the necessary specifications given in 49 C.F.R. §§192 and 195. Most navigable crossings are inspected once a year and all are inspected at least every five years, as required by DOT regulations. Inspection involves divers looking for exposed pipeline, or if the river is turbid, feeling for exposed pipeline. If a pipe is found exposed, the normal procedure is to cover the line with bags filled with a sand and Portland cement mixture.

Because of the difficulty, cost, and equipment needed for repairing a river crossing quickly in the event of a closing of the main line, parallel pipelines are sometimes included at major river crossings at the time of initial pipelaying.

3.3.3.3 Road and Railroad Crossings

For lightly travelled roadways it is sometimes possible to divert traffic and install the pipeline with the standard open ditch technique (Golden et al., 1980). For most roads and railroads, though, open cutting is not permitted and the crossings are most often done with horizontal boring. In most cases a permit is required before the road can be crossed with a pipeline. Horizontal holes of a specified diameter and at depths as specified

in the crossing permit are bored underneath the roadway from one side to the other. The cutting head of the boring tool usually only need be slightly larger than the pipe or casing diameter, if the pipe or casing can be inserted immediately behind the cutter as it advances. The cutting head is driven by a shaft within the pipe, and the shaft is fitted with a spiral conveyer for removing cuttings. This process of boring under the roadway and simultaneously pushing the casing into place is accomplished by use of a heavy tractor on the roadbed serving as a "deadman" anchor (Petroleum Extension Service, 1973). Directional control of the cutter is important because the pipe or casing needs to be straight and at the prescribed elevations. Lubricants such as water or mud slurries are sometimes pumped between the casing and bored hole to make insertion of the casing or pipeline just behind the cutter easier.

The pipeline may be installed directly in the bored hole, or it may be slid into a casing of steel pipe which has been installed first. Some engineers feel that uncased pipelines, sometimes with extra wall thickness, provide a better arrangement for the external loadings experienced by the pipeline under roadways. In many states, however, standard practice requires the installation of such a casing. The pipeline is inserted into the casing in place under the roadway and supported within the casing by spacers or insulators placed at appropriate intervals. Typical spacing is not less than 15 feet, with a minimum of 3 spacers for any road crossing regardless of width (Petroleum Extension Service, 1973). The space between the casing and the pipeline is sealed at each end where the pipeline emerges, but allowance is made for venting. If the pipeline leaks within the casing, the fluids or vapor will leak out through the vents and be readily detected.

Directionally controlled horizontal tunneling may be an alternative to boring. The tunneling technique utilizes a cutting head which is remotely controlled by an operator responding to information monitored at the cutter head. As previously described, the technique has been used at river crossings where it has several advantages over more conventional methods. For road and railroad crossings, however, it is not economically competitive when compared with boring. Conventional tunneling by drilling and blasting is used where the earth beneath the roadway is solid rock or contains large boulders, making boring impractical. This type of tunneling is slow and expensive (Petroleum Extension Service, 1973).

3.3.3.4 Swamps, Lakes, and Unstable Ground

Swamps and lakes are in many ways treated as large river crossings, or sometimes the techniques used are similar to those employed for the wetlands at landfall. Two of the important determining factors influencing the approach are water depth and soil stability. If the water is more than four to five feet deep then conventional barges can be utilized. A barge with a dragline may be used to dig the ditch while another pipelaying barge follows and lays the pipe. Barges of this type usually have a minimum draft of four to five feet.

Tractors can operate in water depths of up to three or four feet, provided the ground is firm and tractors are able to excavate the ditch. If the water is slightly deeper or particularly if the ground is not firm, even for depths less than four feet, then the operator works on constructed pads.

These pads may be made of timber as corduroy roads, or the operator may lift the timber from behind the machine and lay it down in front, thus moving the pad as the machine progresses.

In some cases the contractor may prefer tracked vehicles rather than balloon tires for tractors on wet and soggy ground, as the tracks hold and work better in soft ground. The size of the ditch must be larger in swamps because of the tendency of the trench to cave in. With a ten-inch diameter line, for example, it is common to excavate a vertical ditch two feet wide in dry land, but in a swamp the ditch needs to be seven to eight feet wide at the top.

The pipeline is laid by floating it into place over the ditch when possible. As much of the pipeline as feasible is prewelded because welding on site in the swamp is difficult. The pipe must be weighted to anchor it in the ditch, and this is sometimes accomplished with continuous concrete coating. In recent years, there has been more extensive use of strap-on or bolt-on weights. Buoyancy may be a problem when attempting to backfill and it is sometimes necessary to drain the ditch with pumps before backfilling.

Soils with low load-bearing capacity require special provisions for supporting construction equipment, trenching and backfilling, and handling of the pipeline. Particularly difficult are sandy soils fully saturated with water. Such soils flow quickly so that it is difficult to keep ditches open and vehicles sink into these "quick sands" and resist efforts to pull them out. Withdrawing water stabilizes these soils, and well points are sometimes driven into the ground adjacent to the excavation site and the water pumped out and discharged at some distance away from the work area (Petroleum Extension Service, 1973).

3.4 ROUTINE OPERATION AND MAINTENANCE

Operation of a pipeline system requires relatively few personnel and equipment. A small group of trained staff must be maintained at each compressor station where all operating parameters are monitored. Pump stations may be staffed or they may be operated by remote control from a central dispatch. Maintenance crews may also operate out of the central stations. A company's central dispatch monitors all pipeline systems owned by that company, with a complex communications system. As an example, the central dispatch monitoring Tenneco's 15,000 miles of pipeline located in Texas receives data on all operations for each system every five minutes (NERBC, 1976).

Continuous line pressure monitoring and regular pipeline inspection for leaks are part of regular operating procedure. Surveillance systems vary with individual company practices; they may monitor either line pressure and/or flow rates, and may either trigger shutdown automatically if a change of predetermined magnitude occurs, or require a remotely controlled manual response based on monitored data. These systems are described at greater length in Section 3.5.2.

Most operating procedures involve routine maintenance of the pipeline system and facilities. Maintenance is aimed at both prevention and early detection of pipeline system failures, particularly leaks and breaks in the

trunk line. Onshore there are regular patrols along the right-of-way to observe any changed surface conditions (soil erosion, streambed changes, etc.), indications of leaks (wilting of vegetation is one of the first signs), and activities in the area (such as construction) that might pose a hazard to the pipeline.

The frequency of patrols varies according to federal regulations and the level of activity in the area covered by the pipeline, and may be carried out by air, vehicle or on foot (NERBC, 1976). Observations by regular patrol are also useful in intertidal areas (landfall) where boats are used in addition to air and vehicle patrolling. Inspection at intervals not exceeding two weeks is required (Clark and Terrell, 1978). The monitoring by patrol is most useful for detecting smaller leaks that may not trigger the pressure-sensitive automatic shutdown of the pipeline system.

The detection of a small leak for an offshore line is particularly difficult. Since pressure in an offshore line is continually changing as wells come on or go off, pressure changes due to a small leak may be masked by larger fluctuations. The automatic pressure detection system activates check valves to isolate flow, but industry usually prefers to not place valves in offshore lines except where necessary at platforms and tie-ins. It is felt that a pipeline clear of obstructions offers the best protection because the valves themselves are vunerable to damage. Valves on offshore lines are difficult and expensive to repair because they are buried in mud at the seafloor.

Another system that may be used for leak detection as part of the operating procedure is continual volume flow monitoring at different points in the same pipeline system. A flow inventory is kept to record any loss. Because crude oil is transported from OCS areas to shore by common carrier lines, meters are required at the offshore gathering system and again at the onshore pipeline terminal in order that each producer be properly credited, and these naturally form a good inventory control (Clark and Terrell, 1978).

For onshore natural gas pipelines, the area immediately adjacent to the right-of-way, within 220 yards of the pipeline, is periodically surveyed for buildings intended for human occupancy. The density of such buildings in the survey may affect the frequency of inspections, design of new facilities, or the upgrading of existing facilities (see Section 8.9.1 on Urban Land Use). Equipment and instruments at the compressor, pump, and meter stations are periodically inspected, repaired, and replaced as necessary. Maintenance sometimes includes the use of scraping devices in the pipelines to remove deposits of wax, rust scale, and other material buildup inside the pipe (Petroleum Extension Service, 1973).

Along the onshore right-of-way, there needs to be periodic clearing of vegetation. Maintenance of earth cover over the pipeline is required as well as upkeep of suitable markers, especially at road, railroad, and waterway crossings. The maintenance crew often maintains a stock of supplies such as pipe, leak repair clamps, and other fittings and equipment to use for repairs (NERBC, 1976).

Markers are not required for offshore pipelines, but temporary markers may be used to locate the pipeline in case of maritime construction, and

suitable signs need to be posted on non-production platforms to serve as a hazard area warning. Riser installations at the platforms are visually inspected annually for physical damage and corrosion in and above the splash zone.

The American Petroleum Institute report API RP 1111 "Recommended Practice for Design, Construction, Operation and Maintenance of Offshore Hydrocarbon Pipelines" recommends that the following records should be maintained for the life of the facility, for operations and maintenance purposes: (a) material and construction specifications; (b) route maps and alignment sheets; (c) coating and cathodic protection specifications; (d) pressure test data; (e) corrosion mitigation records; (f) leak and break records and failure investigation records; and (g) records from special inspections, such as external and internal pipe conditions when the line is cut. In addition the following records are recommended for retention for one year: (a) non-destructive inspection data; (b) necessary operational data; (c) pipeline patrol records; and (d) records of safety equipment inspection. Federal regulations require pipeline companies to keep many though, not all, of these records (see, e.g., 49 C.F.R. §§192.243,.491, and .517, and §§195.54, .266, and .310).

3.5 FAILURE AND REPAIR

Gas and oil pipelines are very reliable methods to transport their products, and failures are relatively rare. The mechanism by which the pipeline fails can result from a wide variety of causes, and the impact or damage from the failure can be equally widely varying. A "catastrophic" failure always has some possibility of occurring, no matter how small, thus an "emergency contingency plan" is required for each pipeline system. This plan will indicate the type of immediate action needed and when necessary. In addition to the "emergency contingency plan", a series of routine inspection and maintenance procedures are also followed in order to avoid, or provide early detection of, possible failures. A brief description of failure mechanisms and the probable impact from these failures is discussed below.

Generally, pipeline failures can be divided into: (1) major breaks and ruptures and (2) minor cracks, pinholes and leaks. The most serious of these are obviously the major breaks, not only because a large amount of product is usually lost, but also because their occurrence is usually without warning. Breaks of this type are most often caused by some kind of impact, but very often it has been "set-up" by prior damage to the pipeline due to corrosion, chafing, etc. Therefore a careful inspection program can be of considerable value in avoiding major breaks or ruptures.

Leaks through cracks, pinholes, poor weld points, and other leaks are far more common. They contribute only a small volume of the total quantity spilled, and this usually results from long-term degradation of the pipeline. Automatic monitoring systems can provide rapid detection of major leaks or breaks, but they are not very good at detecting smaller leaks or failures.

3.5.1 Causes of Failure

As previously mentioned, the major cause of pipeline failure is some form of external impact to the pipeline, followed by subsequent corrosion and/or

deterioration of the pipe. The most likely source of the initial damage, as well as the mechanism of subsequent deterioration, differs with offshore pipelines as compared to onshore installations.

Offshore pipeline failure is usually due to impact that is caused by parties unaware of the pipeline's existence. The result is major damage or a rupture in the pipeline, or alternately minor damage that may go undetected until there is considerable deterioration of the pipe. These impacts occur from anchor dragging, damage from commercial fish trawling gear, ship accidents, dredging, or debris discharge. Often the failure may be due to a combination of factors such as impact from one of the above mentioned sources combined with corrosion, natural hazards or construction, or mechanical defects. Because the failure is usually due to a series of events, it is difficult to predict, and the probability of occurrence is also hard to evaluate.

The likelihood of these failures could be reduced by including consideration of them in the siting criteria of the pipeline route. Such criteria are discussed below.

Dragging anchors pose a danger to offshore pipelines crossing anchorage areas and traffic lanes. There are two potential causes of damage, the first due to the dropping of the anchor on a pipeline, and the second due to anchor movement as it is dragged along the sea bottom. In either case, damage to the pipeline may be severe. It is generally concluded that it is practically impossible to bury a pipeline below large anchor embedment depth in soft sediments (Funge et al., 1977), and so route selection for the pipeline usually avoids areas of expected anchorage.

Pipelines and pipeline coatings may be damaged by heavy fishing trawl doors. As with anchor dragging, there are two potential sources of damage caused by the doors being dragged over the pipeline. In tests with various sizes and shapes of doors, impacts were found to be insufficient to cause significant damage to large-diameter, concrete-coated pipe (Gowen et al., 1980). Also in tests, the pullover force resulted in minimal damage or movement of a test pipeline (Gowen et al., 1980). However, any protuberances along the pipeline are vulnerable and also pose a potential source of damage for the fishing gear.

Dredging operations may pose a danger to pipelines, but because permit review for dredging usually includes a check for the location of buried installations, the likelihood of a dredge stiking a pipeline should be small.

Debris either from an accidental discharge, such as heavy cargo rolling off the deck of a supply boat in heavy weather, or an intentional discharge may strike the pipeline forcibly enough to cause damage. For this reason pipeline route selection usually avoids offshore areas designated as dump sites.

Minor or slow leaks of the pipeline are due to corrosion or deterioration of the pipeline. This can be caused by prior impact that may damage the protective coating or due to accumulation of sludge and water at low points in the pipeline. Siting considerations to avoid impact have been previously discussed. Accumulation of sludge and water is prevented by separation of the

free water, gas and oil at the offshore platform. Even with this the pipeline must be regularly cleaned out (pigged) to purge water out of the low spots.

Natural hazards are also a consideration for pipeline safety. Experience has shown, however, that most natural hazards are more important during construction, and evidence indicates the incidence of installed pipe failure due to natural hazards is quite small. Some geologic features may present hazards to the installed pipeline, but failure due to geologic events is relatively rare. A discussion of geologic hazards is given in Chapter VI.

In summary, most pipeline failures are due to equipment malfunction, material deterioration or defects, and to non-induced impact on the pipe. Because of this, the regulations concerning these items are quite extensive and result in avoidance of most of the potential problems. Statistics on causes of failure are presented in Section 9.1.

This is even more true with onshore pipelines where damage due to outside forces used in excavation or other underground construction is the main cause of failure. There are also some minor leaks due to corrosion or deterioration, but these usually result in only small spills and are much more easily contained onshore.

The damage from pipeline failure varies not only with the type of failure, but with the commodity transported. Natural gas is a toxic and flammable substance which may be hazardous to human life, either from inhaling the gas or by fire. Both of these hazards are worse onshore than offshore, particularly if failure occurs where there are high human population densities and property is at risk. Offshore, the result is generally no more than a higher hydrocarbon content in the surrounding waters. The effect of these hydrocarbon compounds on marine life is not well understood. On the other hand, oil spills and/or leaks are generally less damaging and more easily and naturally contained on land. At sea, oil presents severe hazards for marine life and the environment in general. A description of the methods of leak or spill detection and the procedures for cleaning up oil-spills is given below.

3.5.2 Leak Detection

There are three basic methods of detecting leaks from pipeline systems. These are: (1) monitoring of the pressure at various points within the system; (2) automatic monitoring of the flow into and out of the pipeline system; and (3) regular inspection of the pipeline route. Large leaks or spills can be determined by all three methods; however, small leaks are usually detected by the latter procedure.

Large leaks or ruptures of a pipeline cause a substantial change in pressure within the pipeline system. Pressure changes of this magnitude are detected by a pressure monitoring system that automatically shuts down that section of the pipe or provides an alarm which indicates to control dispatch a need for corrective action. The pressure in a pipeline is continuously fluctuating, however, and so the leak or rupture must be large enough to not appear as a simple line surge. Generally the pressure change due to the leak must be on the order of 300 to 500 psi to be noticed. Because of this, medium or small leaks will not be detected by the pressure monitoring system.

In addition to pressure monitoring of the pipeline, there is also a careful measurement of the flow through the pipeline inlet and exit. By this an accurate account is kept of product through the pipeline system. A discrepancy between net inflow and outflow suggests a leak. Due to the required accuracy, volume flow measurements will detect both large and medium leaks. Use of this method for leak detection has an inherently longer response time than does pressure monitoring.

Small leaks cannot be detected by either pressure or volume flow rate measurements. Hence, the procedure for finding small leaks is by regular inspection of the pipeline with observation for "giveaway" signs. In addition, the maintenance program on most pipelines is designed for avoidance and early detection of leaks. Therefore leak surveys are included in the regular inspection procedure. A description of these procedures follows.

Pipeline inspection programs are designed to ensure the proper installation and operation of the pipeline system and are administered by the Materials Transportation Bureau, U.S. Department of Transportation (DOT). There is a Memorandum of Understanding between DOT and the U.S. Department of Interior for coordination of OCS pipeline inspection activities.

Observation of surface waters over underwater oil pipelines can provide an indication of a pipeline leak. Even relatively small leaks will produce a telltale slick. One of the early signs of an onshore leak, on the other hand, is the wilting of surrounding vegetation. Certain connections and sections along the pipeline are known to be more vulnerable than others, and these sections are carefully monitored and observed through periodic inspection. Many types of information gathering methods are used for pipeline leak monitoring, including aerial patrols, on-site surveys, linewalkers, and routine reports from maintenance personnel. The aerial patrol has the advantage of covering long lengths of pipeline, but the experienced linewalkers can usually detect smaller leaks and also determine likely problem areas.

For offshore pipelines, Funge et al. (1977) present the pertinent leakage detection and periodic pressure testing practices as given in Parts 192 and 195 of Title 49, Code of Federal Regulations, and relate that to the adequacy of the Department of Transportation regulations for safety considerations. The regulations call for an annual inspection, a leakage survey, and if practical, a pressure test of pressure relieving equipment.

An alternative to the normal pressure and volume flow monitoring for leaks may be a pressure shut-down test of the pipeline as suggested by the British Institute of Petroleum (1974). The pipeline is shut down under pressure and then a pressure history is recording during the shut-down period. The technique can be very useful in not only detecting a leak, but also determining its magnitude. The shut-down pressure test results in substantial expense to the operator, however, and is recommended only as an alternative by Funge et al. (1977).

3.5.3 Repair Methods

The methods employed for any particular repair are influenced by the nature, size and location of the repair to be made, but the intention to

restore the pipeline to its original specifications or better is always the objective. Repairs must be performed under qualified supervision by trained personnel and the excavation and repair operations cannot result in further damage to the pipeline.

Damage to the pipeline may be in the form of dents, with or without stress concentrations, or leaks. A dent is a depression that produces a gross disturbance in the curvature of the pipe wall without reducing the pipe-wall thickness. Federal regulations at 49 C.F.R. §§192.309 and 192.711-.719 are quite specific as to when and how gas transmission lines must be repaired. Regarding imperfections noticed or made as the pipe is being laid, dents with stress concentrations such as scratches, gouges, grooves or arc burns have to be removed from the pipe, as do dents affecting welds and dents that have a depth of more than 2 percent of the nominal diameter of pipes over 12-3/4 inches in outer diameter. Such dents may not be repaired by inserting patching or pounding it out, but must be removed by cutting out the damaged portion as a cylinder. For other dents, if removal is by grinding, then the final wall thickness must still meet the original pressure carrying specifications.

If an onshore gas transmission line is discovered to have a leak or other imperfection that impairs its servicibility, and if it is feasible to take the segment out of service, federal regulations require that the defects be removed by cutting out a cylindrical piece of affected pipe with the system shut down, and replacing the section with pipe of at least the grade of the original. For offshore lines and onshore lines where it is not possible to shut down the system, the dent, groove, or leak will be covered by a full-encirclement split-sleeve, welded around the pipe. All repairs must then pass a nondestructive test and inspection before being placed back in service.

The repair welding procedures are the same as those required in original construction. All welders performing repair work should be qualified in accordance with 49 C.F.R. §§192.225 and 195.228. Funge et al. (1977) consider the requirements given in the various codes to be compatible with onshore repairs and with offshore repairs where the pipeline is lifted off the bottom for repairs on a barge, or where a dry underwater habitat is used. Because of less experience with underwater welding, the testing and inspection aspects of these repairs are stressed to ensure the integrity of the repair.

Funge et al. (1977) suggest that mechanically applied repair devices could present an acceptable alternative to underwater repairs by welding. Any mechanical coupling must be designed and tested to meet the original pipe specifications for strength and safety. Both 49 C.F.R. §192 and §195 allow for repair by mechanically installing a full-encirclement split sleeve of appropriate design.

3.5.4 Oil Spill Mitigation

Every possible precaution is taken to avoid oil spills. However, even with these precautions some oil spills will occur. The impact of the spill can be mitigated by containment and removal of the spilled oil. This is carried out by mechanical containment of the oil and subsequent recovery.

When an oil spill has occurred, or is likely to occur, mechanical booms or barriers are deployed and manuevered to contain and deflect the slick. Booms have been designed for a variety of special area applications, but they exhibit some common features. The boom extends above and below the waterline and is moored or towed so as to form a fixed, but non-rigid, fence. The boom needs to rise and fall with the water surface. The boom forms a barrier to the movement of the oil slick except as it may be carried under the boom by entrainment. Usually a tow speed of the boom of one knot is a maximum (NRC, 1981).

The spilled oil must be both contained and concentrated to effectively recover the oil by mechanical skimming. The booms are deployed in a "V" or a "U" and then towed slowly to concentrate the oil at the apex of the boom. Skimmers are used to remove and collect the pooled oil. The use of boom and skimmer combinations for oil recovery is effective for slicks from 1 to 5 millimeters thick, if the wave and wind climates allow operation of the equipment. A fairly extensive list of booms and skimmers is given in the U.S. Coast Guard publication "Oil Pollution Response Planning Guide for Extreme Weather" (USDOT/CG, 1980).

Many of the procedures and equipment for mechanical containment and recovery are new and have seen limited operation. They require extensive support equipment, with vessels for towing the barriers and some type of storage facility. The support equipment, the booms, and the skimmers are all vulnerable to bad weather conditions, particularly wind and wave climates and the presence of currents. Booms can also be used to protect environmentally sensitive areas, such as estuaries, from an approaching oil slick.

In addition to mechanical booms, chemical dispersants which break up the oil slick are available. The dispersant alters the surface tension between the oil and the seawater, thus allowing ocean forces to break the oil into small particles for easier assimilation into the water column and later degradation. Although there has been a significant improvement in reducing the toxicity and danger of the chemical dispersant to marine life, these two features still limit the widespread use of chemical dispersants. Biodegradable dispersants that require no premixing have been developed, but their effects on marine life are not well understood. There is usually no attempt for oil recovery with the chemical dispersant system.

Any recovered oil or oily debris needs to be processed in a refinery as crude or as waste. Other disposal techniques are not as satisfactory. The oil takes a long time to decompose if placed in a landfill, and burning of the product in an incinerator may itself produce unacceptable air pollution. Some debris may be used in land cultivation.

The authority to regulate containment and clean-up of oil spills on the OCS is contained in Section 311 of the Federal Water Pollution Control Act, as amended, and the OCS Lands Act, as amended (NRC, 1981). The spiller (owner or operator) is liable for the actual costs of cleanup. All spills or discharges on the OCS or in coastal waters must be reported to the appropriate federal agencies (49 C.F.R. §195.50). For the OCS, the Coast Guard has the authority to initiate clean-up procedures if it considers the actions taken by the spiller to be inadequate.

Companies operating on the OCS often form cooperatives to handle oil spill contingency plans. The cooperative members share the cost of purchasing and stockpiling the materials and equipment. The cooperative maintains the equipment and trains the personnel of member companies or third party contractors to allow rapid deployment at the time of a spill. These cooperatives have to file an inventory of equipment, the composition of the response team, and their contingency plans with the Minerals Management Service, and conduct an annual full-scale drill.

The NRC report "Safety and Offshore Oil" (NRC, 1981) considers the effectiveness of the technology developed for removing or dispersing oil spilled on the ocean to be limited, but also suggests that the organizational aspects of responding to a spill are as important as the technical aspects. The organizational and readiness aspects are addressed in the regulations. The technical problems are difficult because of the severe and changing conditions under which the equipment must be deployed and operated.

3.6 ABANDONMENT

There are occasions where a pipeline may have to be abandoned. One is a temporary measure, usually occurring when the weather becomes too severe for offshore pipelaying to continue. The other is permanent abandonment in which the pipeline is taken completely out of service.

When a pipeline is no longer needed, the cheapest procedure is often permanent abandonment. For permanent abandonment, the pipeline must be disconnected from all sources of product, such as other pipelines, meter stations, and any control lines. In addition, the pipeline must be purged of all product (liquid or vapor) and filled with an inert material. After filling, the ends of the pipe must be sealed. The basic procedures for pipeline abandonment are set forth in 49 C.F.R. §§192.727 and 195.402.

There are times when weather conditions are so severe that offshore pipelaying operations must be suspended and the pipeline has to be temporarily abandoned. In this case the procedure, which usually has to take place as quickly as possible, is as follows (Golden et al., 1980): (1) Pipe welds are completed to provide adequate strength, and all internal equipment such as buckle detectors, x-ray crawlers, and line-up clamps are removed. (2) A cap with a pull eye is welded onto the end of the pipe and the cable from the abandonment winch is connected to the cap. (3) The barge moves ahead until the pipe end reaches the tensioners and the tensioning force is taken over by the abandonment winch. (4) The pipe is lowered by moving the barge ahead until the pipe rests on the bottom. (5) The abandonment cable with auxiliary line is released and a marker buoy is placed.

Retrieval of the pipeline may occur by picking the line up again after the weather has passed and continuing the pipelaying process as before. On the other hand, a new pipe string may be started at the end location of the abandoned pipe and the connection made underwater by mechanical coupling, mechanical flanges, or hyperbaric welding. Although the procedure can be simply described, the abandonment and subsequent retrieval of a pipeline in deep water accompanied by strong currents and heavy seas is usually quite difficult.

3.7 ANCILLARY FACILITIES

The ancillary facilities associated with an oil or gas pipeline include those required during the construction phase of the pipeline project and those required to support operation of the pipeline after construction. Ancillary facilities required during the construction phase are the service base and the pipecoating yard. Each is described below. Generally, ancillary facilities associated with pipeline construction will be accompanied by parallel facilities to support construction activity in the producing OCS field. In this context the ancillary facilities associated with the pipeline are expected to be somewhat minor concerns. After construction the facilities required to support the pipelines are a maintenance yard, required pump or compressor stations, and separation or processing facilities. Requirements for these facilities are also given in this section.

The installation service base is an onshore facility which serves the spread of vessels involved in pipelaying operations. The service base usually covers an area of approximately five acres, mostly as warehouse storage space for storing equipment and maintenance supplies. Usually 200 feet of wharfage is preferred as waterfront, and a minimum water depth of 15-20 feet must be provided to allow vessels access to the wharf. Enough open water must be allowed to give the derrick barge and other vessels room to maneuver.

Road and/or rail access to the service base is necessary for the delivery of materials such as fuel, tools and welding equipment to the base. Sea access is required to ferry crews, materials, and equipment to the pipeline operation and to service the tugs, barges, and other vessels. If the installation site is some distance from shore, for example 150 miles, helicopters will probably replace the crewboats and a helipad will be necessary.

The service base also serves as the storage area for fuels, the source for potable water, and the disposal location for waste. Waste will come from operations at the base itself and from the ships transporting materials to and from the pipelaying operation or offshore platform. Disposal items include sewage, drill cuttings, used engine oil, spills, and vessel bilge water. Because a service base is in operation 24 hours a day, there is noise generated continuously. Sources of noise include compressors, pumps, cleaning equipment, trucks, cranes, generators, and the many other pieces of operational equipment. If the service base is in a relatively quiet, inhabited area, the noise is likely to present a problem (NERBC, 1976).

In most pipelaying operations, the pipe sections are delivered to the lay barge already coated and prepared for welding and subsequent laying. This preparation is carried out at an onshore pipe coating yard. The pipe coating yard serves as the staging area where pipe sections are prepared for shipment to the lay barge. The pipe coating yard requires 30 to 150 acres, most of this area being used for storage of both uncoated and coated lengths of pipe. Roads for the yard machinery run between the stacked rows of pipe, and sand berms are provided where the newly-coated pipe can cool and cure. The pipe coating yard is ideally sited on or near a waterway and in close proximity to a railway or major highway.

Pipes used in the offshore oil and gas operation are usually coated with a mastic compound and weighted with concrete before installation for protection and to overcome flotation. In an eight-month season a pipe coating yard may coat 200 miles of 30-inch diameter pipe with a primer, the mastic compound and three inches of concrete (NERBC, 1976). The pipe sections are delivered to the yard from the steel mill by barge or by rail. In the yard the pipe is handled by fork lifts, small cranes, and trucks and moved from storage to the processing station. At the first station the pipe exterior is cleaned and prepared. The pipe is heated in ovens to remove all moisture and then shot-blasted while hot to establish a good bonding surface. The pipe is first primed with a thin coating of asphalt and petroleum thinner, then the coating of mastic compound is applied. The mastic material is delivered by a heated screw conveyor to the extension die applicator. Each length of pipe is mounted in a device that carries the pipe past the mastic applicator so that a continuous one-half inch layer is laid, completely encircling the pipe. Sometimes this operation is followed by a wrap of fiberglass or tar-impregnated asbestos before the pipe is cooled by spraying the inside with water and the coating quenched. The pipes are then whitewashed with hydrated lime and left to cure. After curing, the insulating properties of the coat are tested with a high voltage (10,000 to 15,000 volts) detector (NERBC, 1976).

In the concrete coating operation, each pipe section is mounted on a rotating device and travels past a set of throwing belts or rollers where the concrete is applied at the rate of about 6,000 feet per minute (NERBC, 1976). As the concrete is applied continuous strands of wire mesh are rolled into the coating for reinforcement. The concrete is made as heavy as possible by the additions of iron ore and specialized mixing techniques to provide the maximum amount of weight. The concrete coating is sprayed with a curing membrane and then cured for at least 28 days. The final step in the coating process involves the moving of the finished pipe from the yard to the lay barges. The pipe lengths are loaded by crane onto a supply barge, then towed by tugboat to the lay barge.

After construction of the pipeline, there are still servicing requirements for the pipeline equipment. Many of these repair and maintenance activities take place underwater. Therefore, the repair and maintenance yards must have facilities for specialized diving support vessels. These vessels usually have onboard workshops that are used to service the divers and the pipelines. These and any other vessels are provided routine maintenance at the repair and maintenance yards. These yards are therefore required to support fairly large vessels and equipment. Experience indicates the yards used for this purpose are the ones that are too big to cater to pleasure boats, but not large enough to be major commercial shipyards. Many of the requirements of the pipeline repair and maintenance yard are similar to other service bases, but the yard must be able to respond rapidly and should be available 24 hours a day.

In addition to the service yard, an operating pipeline requires some additional support facilities. These are compressor or pump facilities located on both the platform and onshore, gas separation facilities located both on the platform and onshore, and oil partial processing facilities or gas processing facilities located onshore. A brief description of each is provided.

Natural gas is often piped directly onshore, with suspended liquids carried in suspension by high pipeline velocities. When pressure boosting is required at the platform, the liquid and gas phases may be separated, the liquid pumped and the gas compressed, and then re-combined if there is only a single pipeline available to shore. If separate oil and gas pipelines are available then the two phases are not combined. Even when separated on the platform the natural gas piped onshore may still contain liquid impurities. For situations where the well pressure is high enough that pressure boosting is not required, the gas will almost certainly contain liquid impurities. The most prevelant liquid impurities are hydrocarbons and salt water. The natural gas, with impurities, is supplied to a natural gas pipeline corporation. This corporation operates the separation and dehydration facility which processes the gas to produce a higher quality gas that is predominately methane. The processed gas is often referred to as "pipeline quality" gas. "Pipeline quality" gas is then transported to users and customers by pipeline systems. The salt water removed at the separation and dehydration facility is disposed of in a manner consistent with federal and state regulations. The liquid hydrocarbons recovered from the natural gas generally belong to the company that operates the producing well. Both salt water and liquid hydrocarbons are usually removed from the separation and dehydration facility by trucks.

Partial processing of the crude oil is usually carried out onshore. Its purpose is to remove the major impurities from a crude oil well stream (after gas separation). Because equipment used at a partial processing facility to remove the emulsified water and sediment from the crude oil is relatively complex, oil partial processing facilities may require a significant onshore area. The techniques for separation include heating, chemical reaction, and electrostatic separation. The partially processed crude is then transported to a refinery by pipeline or tankers. The water that has been removed must also be disposed of and usually requires some wastewater treatment facilities. Because North Carolina has no refineries at present, it is an open question as to the degree the petroleum will be partially processed before shipment to refineries.

After the natural gas is piped ashore, it must undergo processing. The processing separates liquifiable hydrocarbons and salt water from the gas and removes the water vapor remaining in the natural gas (dehydrates the gas) after separation. Typical plants are called separation and dehydration facilities with all processing carried out at a single facility.

A brief description of a typical separation and dehydration plant facility is as follows. The gas received from the well via pipeline is reduced to a velocity considerably less than gas velocity in the pipeline. When this occurs the liquids qradually drop out of suspension with the gas. These liquids are collected and the liquid hydrocarbons go through a series of pressure reductions until they are at atmospheric pressure. As the pressure of the liquid is reduced, vapor is given off. The vapor produced in this way is referred to as flash gas and is compressed back to high (pipeline) pressure. It is then mixed with the higher pressure natural gas.

After separation from liquid impurities (including liquid hydrocarbons) the remaining gaseous impurities, which are primarily water vapor, are removed by dehydration. The gas is bubbled through a series of glycol absorption towers. The glycol removes the gaseous impurities and leaves pipeline quality

natural gas. The amount of impurities that have to be removed determines the amount of "contact" the natural gas must have with the glycol. The regenerated glycol is then piped back to the absorption towers for re-use. In practice the process is a continuous, closed loop system. Separation and dehydration facilities are designed to operate continuously and with a high degree of automation. The local daily work force consists of only 6 to 12 persons. There is a moderate amount of truck traffic to remove the liquid hydrocarbons and salt water separated from the natural gas.

After the gas is processed to recover liquids and remove impurities, it is delivered to a commercial gas pipeline. The specifications for commercial gas include a required energy content of at least 1000 BTU/SCF, less than 320 ppm sulfur, and less than 16 ppm hydrogen sulphide (by volume). Often a supply pressure may also be specified.

Finally there are offshore and onshore pump stations for oil pipelines and compressor stations for gas pipelines. These stations do not require a large amount of area and are relatively unobtrusive. After initial construction, there are no large environmental or cultural impacts associated with these pressure booster stations. Pump stations must usually be located near the landfall of an oil pipeline. Thus, even though it does not require much land, the station may be in an environmentally or culturally sensitive (or economically costly) location. Gas compressor stations usually do not have to be located that close to landfall and are sometimes located with the gas facility. They generally do not present much of a problem.

IV. THE LEGAL CONTEXT

4.1 INTRODUCTION

Any pipeline constructed to transport hydrocarbons from the Outer Continental Shelf to a point onshore will likely cross lands owned by federal, state and local governments, corporations, and private individuals. As such, it will be subject to a variety of laws and regulations at all levels of government. Figure 4-1 gives an overview of the major state and federal authorities which regulate pipeline location, design, construction, and operation.

The purpose of this chapter is to provide an introduction to the legal and institutional context within which pipelines must be considered. Only the major laws and regulations are discussed here, while statutes concerned with specific types of pipeline impacts are mentioned in the sections dealing with those issues. The chapter begins with the discussion in Section 4.2 of right-of-way acquisition on federal lands (both onshore and offshore), state lands, and private lands. State and federal approval of rights-of-way on publicly held lands, along with statutory authority giving pipeline companies eminent domain authority over private lands, will obviously affect the siting of a pipeline. There are also a variety of federal, state, and local permits and regulations which may constrain or restrict pipeline location for environmental, safety, or health reasons; these permits and regulations are considered in Section 4.3. The concluding section (4.4) discusses regulation of the design, construction, and operation of pipelines.

4.2 ACQUISITION OF LAND FOR PIPELINE RIGHTS-OF-WAY

4.2.1 Introduction

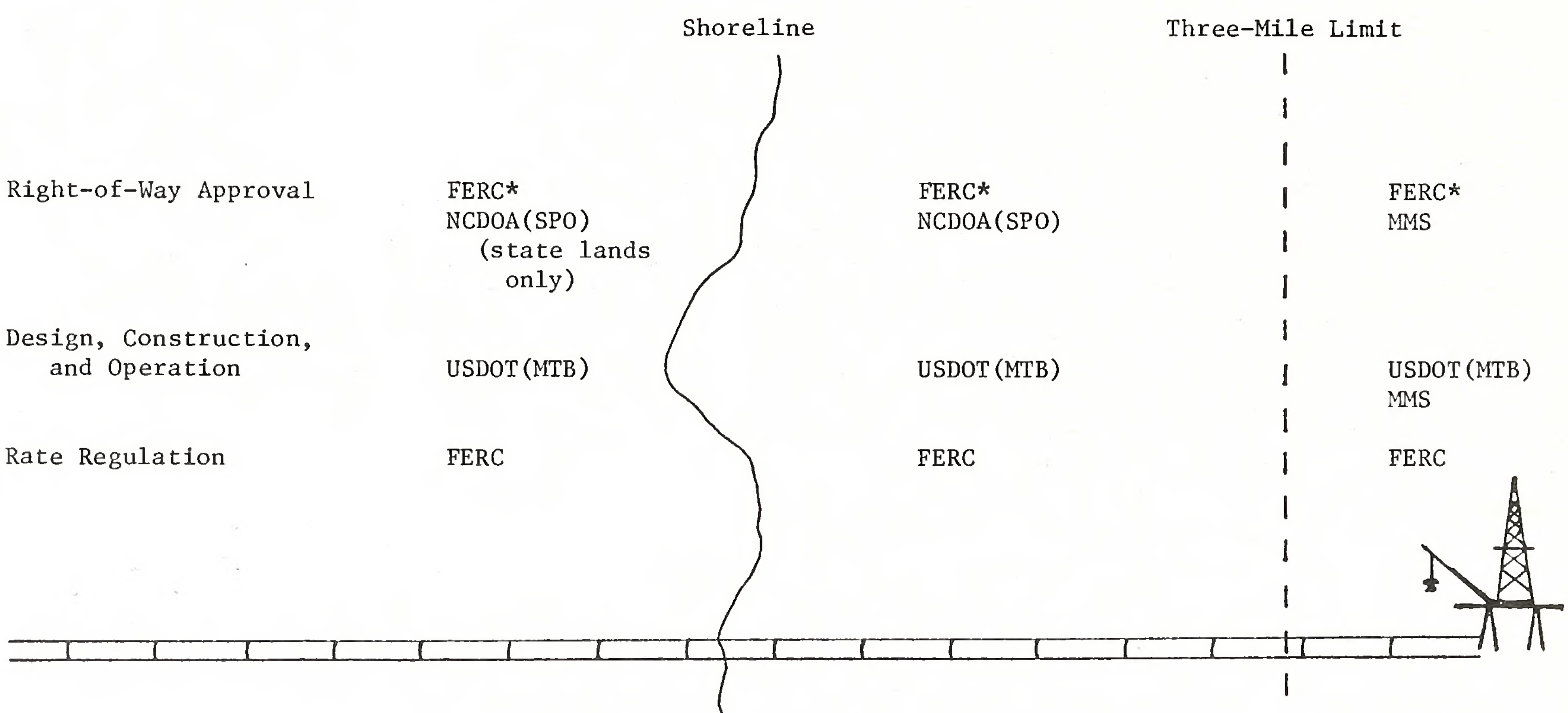
Prior to construction of any pipeline, the pipeline company must obtain a right-of-way through those lands which it intends to cross. If all or part of the proposed route involves land owned by a local, state or federal government, the pipeline company must obtain the permission of the agency authorized to administer that land. If the proposed route crosses any lands which are privately owned, the pipeline company must obtain the right-of-way from those owners through agreement or through exercise of the right of eminent domain.

The right acquired by a pipeline company in a right-of-way for a pipeline is usually in the nature of an easement in the property, whether the property involved is privately or publicly owned. The grant of a right-of-way does not create a possessory interest in the property beyond the limits of the specific right-of-way granted, which are defined in the conveyance.

4.2.2. Federal Lands (Offshore)

The Outer Continental Shelf Lands Act of 1953 (43 U.S.C. §§1331-1356) gave the federal government primary jurisdiction over submerged lands beyond the three-mile limit from shore (Outer Continental Shelf lands), while the states have primary jurisdiction over submerged lands less than three miles from shore by virtue of the Submerged Lands Act of 1953 (43 U.S.C. §§1301-1315). Under the OCS Lands Act, the Department of Interior (DOI) has

Figure 4.1. Regulatory Authorities for OCS Transmission Lines



Abbreviations: FERC: Federal Energy Regulatory Commission
MMS: Minerals Management Service
NCDOA(SPO): North Carolina Department of Administration (State Property Office)
USDOT(MTB): U.S. Department of Transportation (Materials Transportation Bureau)

*Gas lines only

the authority to lease Outer Continental Shelf (OCS) lands under their jurisdiction for energy development. Until 1982, the Bureau of Land Management (BLM) within the Department of Interior had primary responsibility for leasing these lands for oil and gas recovery, while the United States Geological Survey (USGS) within DOI supervised exploration, development, and production activities in the post-leasing phase. These functions have now been delegated to the newly created Minerals Management Service (MMS).

In addition to its leasing responsibilities, the MMS has authority (inherited from BLM) to grant rights-of-way on the Outer Continental Shelf (up to the three-mile limit) for pipelines transporting oil or gas from OCS lease tracts to shore. The procedure for applying for a pipeline right-of-way and the general conditions which attach to a right-of-way grant are set forth in 43 C.F.R. §3340. An applicant for such a pipeline right-of-way may be the lessee of a tract of OCS land, or it may be an independent pipeline company. If the right-of-way applied for crosses mineral leases or rights-of-way other than those of the applicant, the applicant must submit with his application a statement that he has notified these parties (the affected parties have 30 days from service of notice to comment to MMS on the granting of the right-of-way). In addition, if the right-of-way crosses any area restricted from oil and gas activities, the applicant must show consent to the granting of the right-of-way by the federal agency in charge of such restricted area (for instance, the Secretary of Commerce must certify a right-of-way which will cross a Marine Sanctuary). Finally, if the proposed route crosses any state submerged lands, the applicant must show evidence that the states so affected have received and reviewed the application, and must include in the application any recommendations by the state regarding the location of the route. (See Section 4.2.4 regarding easements across state land.)

In considering the application for a right-of-way, regulations require MMS to consider the potential effect of the pipeline on the human, marine, and coastal environments during the construction and operational phases of the pipeline (43 C.F.R. §3340.2-2). MMS will prepare an environmental analysis assessing the impact of the pipeline on these environments (other environmental reviews may be required in relation to pipeline construction; see Section 4.3.1). MMS may attach, as a condition to approval of the right-of-way, special stipulations designed to ensure that these environments and resources are protected. Any right-of-way grant remains in force as long as the pipeline is properly maintained and used for the purposes for which the grant was made, unless otherwise stated in the grant.

In addition, MMS inherited from USGS the authority to grant a "right of use and easement" for any gathering lines or other pipelines "wholly contained within the boundaries of a single lease, the boundaries of unitized leases, or the boundaries of contiguous (not cornering) leases of the same owner or operator" (Memorandum of Understanding between BLM and USGS, signed August 1980). Gathering lines are pipelines used to bring oil or gas from a well to a collection point within an offshore field. Conditions for the granting of a right of use and easement are set forth in 30 C.F.R. §§250.18-.19.

4.2.3. Federal Lands (Onshore)

The Mineral Leasing Act of 1920 (30 U.S.C. §185) provides for granting rights-of-way for oil and gas pipelines through federal lands, except lands in the National Park System, Indian trust lands, and OCS lands. Where the surface of all the onshore federal lands involved in a proposed right-of-way is under the jurisdiction of one federal agency, that agency is authorized to grant the right-of-way. On the other hand, if the surface of the federal lands involved is administered by two or more federal agencies, then the right-of-way will be approved by the Secretary of Interior after consultation with the agencies involved.

Construction of a pipeline through a federal wildlife refuge area falls within the ambit of the Mineral Leasing Act of 1920, but specific requirements are set forth at 50 C.F.R. §29 for those areas. These regulations require that an application contain sufficient information to enable the Fish and Wildlife Service to satisfy environmental, cultural, historical and archeological protection requirements. The Fish and Wildlife Service will not grant permission for the right-of-way unless the construction is deemed to be compatible with (i.e., not interfering with or detracting from) the purposes for which the refuge was established.

The secretary of a military department, if he finds that it will be in the public interest and not injurious to the interests of the United States, may grant easements for rights-of-way for oil and gas pipelines over, in, or upon public lands permanently reserved for the use of his department and other lands under his control (10 U.S.C. §§2668-2669).

If the route of a pipeline would take it through a national park, this would require a permit which satisfies the requirements of 36 C.F.R. §5.7 for a written agreement with the United States. The regulations at 36 C.F.R. §14 set out the application procedures and the conditions for granting a right-of-way across a national park. The right-of-way is issued by the Director of the National Park Service in the form of an easement, license, or permit.

Finally, any pipeline in the right-of-way of federal aid highways or federal aid highway projects must receive the approval of the regional administrator of the Federal Highway Administration (23 U.S.C. §1.16; 23 C.F.R. §§1.23-1.27).

4.2.4. State Lands

The Submerged Lands Act of 1953 gave the coastal states title to land and resources beneath navigable waters to a limit of three geographical miles from shore (except for Texas and Florida, for which the limit is 9 miles). The United States retains certain powers over navigation, commerce, and international affairs in these waters.

In North Carolina, the Department of Administration (DOA) has been given the authority to issue easements for construction on state owned land both onshore and within the three-mile limit offshore (N.C.G.S. §§146-11,12). Any pipeline passing through state waters offshore, or through state lands onshore (including ocean beaches) would have to obtain an easement from DOA for the

proposed route. Crossings of submerged lands and onshore state lands require separate easements, but these may be incorporated in the same instrument, if both are necessary. In order to issue either the onshore or offshore easement, the DOA must consider "if all the aspects of the public interest will best be served" by the granting of the easement (1 N.C.A.C. 6B .0604, .0608). The DOA may conduct its own environmental review prior to granting the easement, or it may rely on environmental assessments conducted by other state and federal agencies for the pipeline project. The term of the easement is decided on a case-by-case basis, but it has been the practice to grant pipelines an easement in perpetuity (Conyers, 1981).

N.C. General Statute §113-34 requires that a permit for any construction on the floor of a state owned lake be obtained from the Division of Parks and Recreation. Contacts at this agency indicate it is unlikely that a permit would be issued for a permanent structure on the bottom of a state lake (Webster, 1981).

4.2.5. Private lands

Pipeline rights-of-way across private lands may be obtained either through negotiated agreement or through the exercise of the right of eminent domain. The right of eminent domain has been traditionally defined as the power to take private property for public use, and this power has generally been granted to pipeline companies by state and federal law. Thus, pipeline companies may acquire the necessary right-of-way on privately held land from reluctant owners by exercising their eminent domain authority (also known as "condemnation authority") in a court proceeding, if the company is unable to acquire the right of way through private contract.

An oil or gas pipeline constructed from the OCS to an onshore location is considered an interstate pipeline, since it originates outside the state (15 U.S.C. §717a(7)). Under the Commerce Clause of the U.S. Constitution, the federal government has preemptory power to regulate such interstate transportation of resources, if it so chooses.

The Natural Gas Act (15 U.S.C. §§717-717w) gives the Federal Energy Regulatory Commission (FERC) the authority to regulate the construction and siting of interstate gas pipelines through issuance of a certificate of public convenience and necessity. No interstate pipeline company may engage in the transportation of natural gas without first obtaining this certificate from FERC, and the certificate will not be issued unless FERC is satisfied that the public convenience and necessity requires, or will require, the construction, acquisition, or operation which is proposed. The granting of this certificate gives the holder the right of eminent domain to acquire private lands onshore for the necessary right-of-way, if it cannot acquire those lands by contract or agreement. Once FERC has issued a certificate, there exists a strong presumption in favor of the landfall and transmission route chosen. This presumption could be important if a state were to try to deny a pipeline company the needed permits (Morrell, 1977).

The FERC has issued detailed guidelines (18 C.F.R. §2.69) for the planning, locating, clearing, and maintenance associated with gas pipeline construction authorized by a certificate of public convenience and necessity. Included in these guidelines is the requirement that pipeline construction

should be undertaken in a manner which minimizes adverse effects on scenic and historic sites, wildlife, and recreational values. Consideration should also be given to the utilization or enlargement of existing rights-of-way belonging to the applicant or others, such as existing pipelines, electric powerlines, highways, and railroads.

Oil pipelines are also regulated by the FERC under the Department of Energy Organization Act (42 U.S.C. §7155), but current regulations do not require the granting of a certificate of public convenience and necessity by FERC as a prerequisite to pipeline construction. Also, federal law does not give oil pipeline companies condemnation power, so they must rely on state condemnation authority. North Carolina law (G.S. §62-190) gives oil pipeline companies, including those constructing interstate pipelines, eminent domain power in North Carolina (Colonial Pipeline Co. v. Neill, 296 N.C. 503, 1979). The pipeline company must be transporting oil for the public for compensation, and must be either incorporated under the laws of North Carolina, or a foreign corporation domesticated under the laws of North Carolina. No state certificate of public convenience and necessity need be obtained for an interstate oil pipeline, by virtue of a 1964 Utilities Commission ruling which stated that the state certificate requirement in G.S. §62-110 applies only to intrastate pipelines (In the matter of Plantation Pipeline Company, N.C. Utilities Commision, Docket No. G-27, May 19, 1964). This ruling leaves the state in the potentially awkward position of having granted eminent domain authority to interstate oil pipeline companies without reserving any direct state control over the route chosen.

Finally, the U.S. Department of Transportation (DOT) approves all gas pipeline right-of-way locations under the Natural Gas Pipeline Safety Act of 1968 (49 U.S.C. §§1671-1686). The DOT, which is charged with regulating the design, construction, and operation of interstate pipelines (see Section 4.4), has established design and construction requirements for different population density classifications (49 C.F.R. §192). These standards may influence the siting of gas pipelines.

4.3. ENVIRONMENTAL REGULATION OF PIPELINES

In addition to those laws granting rights-of-way and condemnation authority to pipeline companies, a variety of federal, state, and local laws address the impacts which pipelines and similar development projects may have on environmental resources and economic activities. By limiting the impacts that pipeline construction and operation may create, these laws may have considerable influence on pipeline siting. The following sections discuss the more significant provisions of these laws.

4.3.1. Federal Regulations

Environmental Review and Regulation. The National Environmental Policy Act (NEPA; 42 U.S.C. §§4321-4347) requires that an Environmental Impact Statement (EIS) be prepared by the responsible federal agency for every major federal action "significantly affecting the quality of the human environment." The intent of the EIS process is to ensure that public officials fully consider the environmental consequences of their decisions. The document serves as a public record of the factors considered and people consulted and as a guide for future decision-making.

Two EIS's prepared before the lease sale may influence pipeline siting in general terms. These are the statements covering the Five-Year Leasing Schedule and the particular sale in question (the Final EIS for Sale 56 was issued in January, 1981). After the sale has taken place, as many as three EIS's may be written which specifically address the question of OCS pipeline siting, in addition to the environmental assessment performed by MMS for all right-of-way applications. First, under the OCS Lands Act and its associated regulations, a lessee must submit to MMS a development and production plan prior to any development or production activities. The plan must include an Environmental Report which, among other things, describes the means proposed for transportation of oil and gas to shore, the routes to be followed by each mode of transportation, and the estimated quantities of oil or gas, or both, to be moved along such routes. Prior to approval of a development and production plan, MMS will review the environmental impacts of the activities proposed to determine whether approval would constitute a major federal action significantly affecting the environment. If so, and if the activities have not been adequately considered in a previous EIS, then an EIS will be prepared by MMS covering the activities described in the development and production plan or in a number of such plans. The OCS Lands Act directs that an EIS must be prepared on a development and production plan at least once in each area or region.

The second type of EIS which may be prepared is based on an OCS Lands Act provision (43 U.S.C. §1351(k)) requiring that any part of the development and production plan relating to a natural gas pipeline must be submitted to FERC. The Secretary of the Interior and FERC together will determine whether an EIS or environmental studies should be prepared regarding the proposed gas pipeline, and by which agency.

Finally, FERC has authority to conduct its own review under the Natural Gas Act prior to issuing a certificate of public convenience and necessity for a natural gas pipeline. This certification review may be supplementary to any EIS prepared by the Department of Interior on a natural gas pipeline, but should not be duplicative. Officials at FERC indicate that such a review is almost always required before granting a certificate for an interstate gas pipeline (Hoffman, 1981).

As required by NEPA and the implementing regulations issued by the Council on Environmental Quality (40 C.F.R. §1502), every EIS must contain a consideration of alternative actions to the one being proposed, short- and long-term environmental impacts, and irreversible commitments of resources which would be involved in the proposed activity. During the course of EIS preparation, the requirements of a number of other environmental laws are considered and their administering agencies consulted. These statutes include: the Endangered Species Act of 1973 (16 U.S.C. §§1531-1543); the Marine Protection, Research, and Sanctuaries Act of 1972 (33 U.S.C §§1401-1444 and 16 U.S.C. §§1431-1434); the National Historic Preservation Act of 1966 (16 U.S.C. §470); the Fish and Wildlife Coordination Act (16 U.S.C. §§661-666); and the Federal Coastal Zone Management Act of 1972 (16 U.S.C. §§1451-1464).

Permits for Construction in Navigable Waters. Section 10 of the Rivers and Harbors Act of 1899 (33 U.S.C. §403) prohibits construction of any structure or other impediment to navigation in navigable waters (including OCS waters) without first obtaining a permit from the U.S. Army Corps of Engineers.

Section 10 permit requirements cover the construction of pipelines, piers, wharves, cables, conveyors, tunnels, dams, dikes, and bulkheads. Moreover, the permit is required for any excavation, construction, dredging or dispersal in navigable waters. The regulatory policies applied by the Corps in reviewing Section 10 permit applications are set forth in 33 C.F.R. §320. The review process for permit applications includes review by a variety of agencies in addition to the Corps, as mandated under various statutes (e.g., the Endangered Species Act; the Marine Protection, Research, and Sanctuaries Act; the National Historic Preservation Act of 1966; the Fish and Wildlife Coordination Act; and the Coastal Zone Management Act).

Under Section 9 of the Rivers and Harbors Act of 1899 (33 U.S.C. §401; 49 U.S.C. §1655(g)), the Coast Guard must issue a permit for elevated pipeline crossings of navigable waterways.

<u>Dredge and Fill Activity</u>. Any dredge and fill activity associated with the construction of pipelines in navigable waters will require both a Section 10 and a Section 404 permit from the Army Corps of Engineers. The Section 10 permit, discussed in the previous section, would be needed to conduct the necessary dredging operations. The Section 404 permit, required by Section 404 of the Federal Water Pollution Control Act Amendments of 1972 (P.L. 92-500; 33 U.S.C. §1444), is necessary for any <u>discharge</u> of dredged or fill materials into the waters of the United States. (Section 404 applies to the "waters of the United States", whereas Section 10 applies only to work affecting <u>navigable</u> waters. "Waters of the United States" is a much broader term, including not only U.S. navigable waters and their adjacent wetlands (the Section 10 jurisdiction), but also (1) tributaries to navigable waters of the U.S., including adjacent wetlands; (2) interstate waters and their tributaries, including adjacent wetlands; and (3) all other waters of the U.S., the degradation or destruction of which could affect interstate commerce (33 U.S.C. §1251; 42 F.R. 37127, 1977)). The review process for the Section 404 permit is basically the same as that for the Section 10 permit, and if both are required for a particular project, they will usually be considered together.

If dredged materials are to be dumped in the ocean, Section 103 of the Marine Protection, Research, and Sanctuaries Act (16 U.S.C. §1431) prescribes that a permit must normally be obtained from the Army Corps of Engineers before transporting those materials to be dumped. However, current regulations specifically exempt ocean dumping in connection with pipeline placement from the §103 permit requirements (40 C.F.R. §220.1).

<u>OCS Lands Act Regulations and Lease Stipulations</u>. When a lease is granted by the United States to develop and produce oil and gas in a particular area of the OCS, the lease binds the lessee to the requirements of the OCS Lands Act and any regulations promulgated pursuant to that Act. MMS regulations governing administration of the leasing program and granting of pipeline rights-of-way are found at 43 C.F.R. §3300, while regulations for lease exploration, development and production are located at 30 C.F.R. §§250 et seq. The former establish a number of general requirements which an applicant must accept as a condition for obtaining a pipeline right-of-way. For example, the pipeline must be maintained so as "not to pose an unreasonable obstruction to fishing and shipping operations," and the right-of-way holder agrees to suspend operations if the pipeline threatens or results in "serious,

irreparable or immediate harm to life (including fish and other aquatic life), to property, to mineral deposits or the marine, coastal, or human environment."

In addition to these regulations, MMS may attach specific stipulations to the leases for all or only certain tracts in a particular lease sale area. In Lease Sale 56, stipulation number 9 specifically addresses pipeline transportation. The stipulation, included in all Sale 56 leases, requires the utilization of pipelines for transportation of oil and gas from the OCS "(1) if pipeline rights-of-way can be determined and obtained; (2) if laying such pipelines is technically feasible and environmentally preferable; and (3) if, in the opinion of the lessor [MMS], pipelines can be laid without net social loss, taking into account any incremental costs of pipelines over alternative methods of transportation and any incremental benefits in the form of increased environmental protection or reduced multiple use conflicts." The lessor (MMS) retains the right under this stipulation to require that any pipeline used to transport production be placed in certain designated management areas. MMS's decision on what form of transportation will be employed is made within the context of an intergovernmental planning process for OCS oil and gas transportation. A key product of this planning process is a Regional Transportation Management Plan, written by a group of representatives from federal agencies, affected states, and private interests, and which serves as an advisory document in identifying acceptable land and water areas in each leasing region for transporting OCS oil and gas. The first draft of the Regional Transportation Management Plan for the South Atlantic was published in 1981. Finally, the stipulation states that following the installation of a pipeline, "no crude oil production will be transported by surface vessel from offshore production sites, except in the case of emergency."

In addition, three other stipulations included in Sale 56 leases impose certain requirements or conditions on pipeline placement within lease tracts:

- Lease Stipulation Number 1 requires the lessee to locate any offshore pipeline so as not to affect historical or archeological structures.
- Stipulation Number 2 requires the lessee "to undertake any measure deemed economically, environmentally, and technically feasible to protect live bottom areas" from oil and gas operations, including, if necessary, pipeline route relocation to avoid such areas.
- Stipulation Number 7, applicable only to certain tracts identified as susceptible to mass sediment movement, states that pipelines will not be permitted within potentially unstable areas unless the lessee either demonstrates the unlikeliness of sediment movement or adequately designs the pipeline to withstand such a hazard.

For each OCS area, the MMS also issues a set of rules to supplement the regulations at 30 C.F.R. §§250 et seq. Known as OCS Orders, these regulations govern various aspects of exploration, development and production. OCS Order No. 9 deals with oil and gas pipelines formerly under USGS jurisdiction (primarily gathering lines); but the order currently is applicable only in the Gulf, and its corresponding version for the Atlantic is now being drafted.

<u>Vessel Navigation and Safety</u>. The Coast Guard is charged with regulating navigational safety under the Ports and Waterways Safety Act (33 U.S.C.

§§1221-1232) and the OCS Lands Act. Based on these authorities, the Coast Guard has promulgated many detailed rules on lighting of vessels, signals, vessel maneuvering, aids to navigation, safety equipment, vessel speed, draft limitation, and anchoring. The Coast Guard also has the authority to control vessel traffic in certain areas, usually port areas, to prevent collisions or groundings (33 C.F.R. §161). In addition, the Coast Guard has established procedures and standards for the handling, loading, discharge, storage, movement, control, and disposition of explosives or other dangerous articles and substances on vessels subject to the Ports and Waterways Safety Act (46 C.F.R. §146). These various regulations may have an effect on the operations of pipelaying vessels, particularly at landfall areas.

Other Federal Regulations and Programs. The Fishery Conservation and Management Act of 1976 (16 U.S.C. §1801) provides for the creation of eight Regional Fishery Management Councils. The South Atlantic Fishery Management Council is responsible for the area off the North Carolina coast.

The major function of the Council is to prepare Fishery Management Plans for approval by the Secretary of Commerce which contain recommended regulations designed to produce the annual optimum yield from the fishing stocks in the region. Any pipeline emplacement which is inconsistent with the management activities detailed in a plan might generate comments to permit applications under these regulations. Presently there is one Fishery Management Plan for the South Atlantic region, for spiny lobster, with several more in preparation.

The Land and Water Conservation Fund Act of 1965 (16 U.S.C. §§4601-4 to 4601-11) earmarks federal funds to assist the states in developing and acquiring parks and recreation areas. Pipeline construction across any areas acquired with land and water conservation fund monies requires the approval of the Secretary of the Interior.

4.3.2 State Regulations (North Carolina)

Coastal Area Management Act. The Federal Coastal Zone Management Act of 1972 (16 U.S.C. §1451) established an assistance program to those states with coastal management programs approved by the National Oceanic and Atmospheric Administration's Office of Coastal Zone Management. The North Carolina Management Program, based largely on the 1974 North Carolina Coastal Area Management Act (CAMA; N.C.G.S. §113A-100), was approved on September 1, 1978. The primary policy-making body for the program is the Coastal Resources Commission (CRC); administration is handled by the Office of Coastal Management (OCM) within the Department of Natural Resources and Community Development.

The Coastal Management Program and CAMA established a two-tiered approach for managing the coastal resources of the twenty-county coastal area. Any development activities occurring wholly or partially in designated Areas of Environmental Concern (AECs) require a CAMA development permit. The definition of AECs is set out in detail in the State Guidelines for Areas of Environmental Concern (15 N.C.A.C. 7H), but basically includes coastal wetlands, estuarine waters, public trust areas, estuarine shoreline, ocean hazard areas (including beaches, frontal dunes, inlet lands, and other areas subject to excessive erosion or flood damage), and some natural and cultural

resource areas. Development activities outside these AECs do not require a CAMA development permit but are still subject to other federal, state and local regulatory authorities, and these agencies are required to consider coastal policies in their permit or regulatory decisions (Exec. Order No. 15, Gov. James B. Hunt, Jr.).

Any pipeline to shore would have to cross at least one AEC and therefore would require a CAMA development permit. These permits are of two types: if the activity is considered a "major development," the CAMA permit must be obtained from OCM; "minor development" permits are handled by local government units, contingent on CRC approval of a local implementation and enforcement plan. "Major development" is defined by CAMA as any development which: (a) requires permission, licensing, approval, certification, or authorization by the Environmental Management Commission, Mining Control Board, or the Departments of Human Resources, Natural Resources and Community Development, or Administration; (b) occupies a land or water area in excess of 20 acres; (c) contemplates drilling or excavating natural resources on land or underwater; or (d) occupies on a single parcel a structure or structures in excess of a ground area of 60,000 square feet. Under this definition, oil and gas pipelines coming from offshore would require the CAMA major development permit, since permits from DNRCD and DOA would be needed for pipeline construction, and the land and water area of the pipeline would exceed 20 acres.

In considering the application for a CAMA major development permit, the Act directs that the CRC consider the following in making its permit decision: (1) the State guidelines for AECs promulgated under CAMA; (2) local land use plans (see Section 4.3.3); (3) general policy guidelines for the coastal area promulgated by the CRC; and (4) any other criteria listed in G.S. §113A-120.

The federal Coastal Zone Management Act also gives a state with an approved Coastal Management Program the authority to certify whether certain federal activities having a significant effect on the coastal zone of the state are consistent with the state program. Currently this "consistency review" is applicable to "any person proposing to conduct an activity which requires a federal license or permit and which affects land and water uses in the coastal zone." (16 U.S.C. §1456) Pipeline construction would be subject to this consistency review as the law stands now. There have been recent attempts to redefine the consistency regulations, however, and there is some uncertainty as to the scope of the consistency review in the future.

The consistency review in North Carolina is performed by the Office of Coastal Management. OCM may certify the activity as consistent, in which case the application may be processed for issuance of the federal license or permit. Alternatively, OCM may object to the permit or activity, in which case no permit or license may be issued unless the Secretary of Commerce overrides the state's objection on the grounds that the activity is "consistent with the objectives" of the Act or "is otherwise necessary in the interest of national security." (16 U.S.C. §1456)

It should be noted that a federal consistency determination does not require a federal agency to approve the activities which the state agency has found consistent with its program.

Dredge and Fill Regulations. In addition to the federal dredge and fill permits, the State Dredge and Fill Act (N.C.G.S. §113-229) requires that a permit be obtained from the Office of Coastal Management before engaging in any dredge and fill activities in estuarine waters, marshlands, tidelands, or state-owned lakes. Based upon regulatory criteria promulgated under the Act, the OCM may approve the permit, issue the permit with conditions, or deny the permit. These criteria primarily address and are designed to minimize potential adverse environmental impacts of dredge and fill activity.

The Corps of Engineers has recently agreed to issue a "general permit", under which the Corps will not require a separate review prior to issuing Section 10 and 404 permits if the state has already issued a State Dredge and Fill Permit, a CAMA permit, and a 401 Water Quality Certification for a particular project. The Corps permit will automatically be granted following issuance of these state permits. Interviews with Corps representatives indicate that complex projects generally fall outside the scope of the general permit, and it is likely that pipeline construction would require separate federal and state review for issuance of their respective dredge and fill permits (Hollis, 1981).

Sedimentation Control Regulations. Any proposed land disturbing activity which will be undertaken on a tract of land of one or more acres and will involve uncovering more than one contiguous acre requires the submission of a Sedimentation Control Plan to the Division of Land Resources (DLR) under N.C. Gen. Statute §113A-54. "Land disturbing activity" is defined as any use of the land that results in a change in the natural cover or topography that may cause or contribute to sedimentation. The control plan must provide control for the calculated peak rate of runoff from a 10-year frequency storm. The plan should also include a description of the proposed development of the site, measures to meet mandatory and performance standards, and downstream protection of stream banks and channels. The DLR may require that the plan be modified, completely changed, or conditions added before the plan is approved.

It should be noted that local governments may supersede the state law by adopting their own erosion control ordinance, which must be at least as stringent as state law. In the coastal area, only New Hanover County and the communities of Havelock, Jacksonville and Ocean Isle Beach presently have local erosion control ordinances.

Water Quality Regulations. Any person who engages in an activity that may result in a discharge to navigable waters, and which requires a federal permit, must obtain a 401 Water Quality Certification. This certification, based on Section 401 of the Federal Water Pollution Control Act Amendments of 1972, requires that such a discharge be in compliance with state water quality standards. Since the activity associated with construction of onshore and offshore pipelines would require various federal permits and would likely result in some type of discharge to navigable waters, a 401 Water Quality Certification would be required. The North Carolina Division of Environmental Management is the certifying agency.

Environmental Studies Requirements. Under the State Environmental Policy Act (SEPA; N.C.G.S. §113-A-1) any project which involves the expenditure of state monies for actions which may significantly affect the quality of the state's environment must submit either an environmental impact statement or negative

declaration. The North Carolina EIS would probably not be required for the construction of onshore pipelines since state monies would not be expended for these projects. However, SEPA also allows local governments, by ordinance, to require an EIS for certain private development activities.

A second and distinct form of environmental review is an environmental assessment which may be required under G.S. §143B-437. Under this statute an environmental assessment should be prepared by the N.C. Department of Commerce in conjunction with DNRCD to assess the impact of new and expanded industries. Although this procedure has been rarely used in the past, there are indications that it may be employed more frequently (Schecter, 1981).

Dam construction. Construction of pipelines across wide rivers is often accomplished by damming portions of the river during the construction process. State law provides that any person proposing to construct, repair, modify or remove a dam must file a statement with the Division of Land Resources concerning the proposed activity (N.C.G.S. §143-215.27). A Dam Safety Permit is required prior to construction if the height of the dam is to be 15 feet or greater (from top of dam to lowest point at downstream toe) and the impoundment capacity will be 10 acre-feet or greater at the top of the dam. If the construction of the dam will result in a body of water of 100 acres or more, an Impoundment Permit will also be required from the Department of Human Resources.

Pipeline construction across large rivers would probably use a coffer dam method of temporarily damming up the river, which would not result in any impoundment of water. Therefore, the Dam Safety Permit and Impoundment Permit would probably not be required.

Public Trust Doctrine. The Public Trust Doctrine is based on a common-law concept which gives the public right to full and unobstructed use of navigable waters and certain lands for the purpose of navigation (Gaither v. Albemarle Hospital, 235 N.C. 431, 1952). Under this doctrine any unreasonable obstruction in navigable water would be considered an unlawful public nuisance. Nevertheless, holders of easements across submerged lands may construct structures on their lands, so long as these structures do not interfere with the public's right of navigation (Finch, 1981).

4.3.3 Local regulations

The Coastal Area Management Act requires that local land use plans must be prepared by all units of local government in the coastal zone, and that these plans must be approved by the CRC according to CRC-adopted guidelines. The land use plans classify all the land within the county or municipality into five general land classes: developed, transition, community, rural, and conservation. When the CRC issues CAMA development permits these land use plans must be consulted, and all permit decisions must be consistent with those plans. Thus the land classification system functions indirectly as a regulatory mechanism. OCM also consults local land use plans when making its consistency review of federal license or permit applications.

The ability of local governments to directly regulate the construction and siting of pipelines through zoning ordinances and other regulations is an area of some debate. Cities and counties in North Carolina have the power to exercise land use controls pursuant to the police powers delegated to them by

the state (N.C.G.S. §§153A-123 and 160A-75). Courts in other states, while recognizing the local interest in controlling development, have nevertheless generally struck down local zoning ordinances which attempt to forbid the siting of a pipeline in a particular jurisdiction (New York State Natural Gas Corp. v. Town of Elma, 182 F. Supp. 1, W.D.N.Y. 1960; Transcontinental Gas Pipeline Corp. v. Borough of Milltown, 93F. Supp. 287, D.N.J. 1950). The basis of these decisions is (1) that such a prohibition is an unconstitutional restraint on interstate commerce, and (2) that the power of eminent domain given to pipeline companies both conflicts with and predominates over local zoning ordinances. Further, where the pipeline is an interstate pipeline and therefore subject to federal regulation, this federal scheme of regulation is given precedence over local zoning efforts in governing the utility's eminent domain rights. Nevertheless, while these courts agree that a total prohibition is unconstitutional as an undue burden on interstate commerce, reasonable regulation (such as requiring that alternative sites be considered) by a county or municipality is acceptable.

It should be noted that some courts have disagreed with the holding that a local jurisdiction may not completely prohibit pipeline or other utility line construction through zoning. These courts have held that the mere fact that a utility can hold and take land does not force the conclusion that it can take the land of its choice without regard for local ordinances (New York State Electric and Gas v. Statler, 122 N.Y.S. 2d 190, 1953). To date, the North Carolina courts have not considered the question.

Several ways have been suggested by which local governments can influence pipeline placement other than through local zoning ordinances (Hershman and Fontenot, 1976). The first means is through the development of a local land use plan, discussed previously. Second, the administrative review procedures provided for in the OCS Lands Act regulations give affected state and local governments the authority to review and comment on development and production plans. In their evaluation of these plans (which include pipeline routing), the USGS may accept the recommendations of the executive of an affected local government, if the recommendations "provide for a reasonable balance between the national interest and the well-being of the citizens" of the affected area (30 C.F.R. §250.34-2).

Finally, several counties may work together to form a regional plan which suggests areas suitable for pipeline corridors. In this manner, the localities may be able to place a smaller burden on interstate commerce and also present positive legislation to guide pipeline construction, rather than reacting to proposed locations by attempting to exclude construction.

4.4 REGULATION OF PIPELINE DESIGN, CONSTRUCTION, AND OPERATION

4.4.1 Department of Transportation

Under the authority of the Natural Gas Pipeline Safety Act of 1968, (49 U.S.C. §§1671-1686) and the Hazardous Liquid Pipeline Safety Act of 1979 (49 U.S.C. §§2001-2014), the U.S. Department of Transportation's Materials Transportation Bureau issues and enforces design, construction, operation, and maintenance regulations for all interstate pipelines. These regulations are set forth at 49 C.F.R. §192 for gas pipelines and 49 C.F.R. §195 for liquid pipelines.

To avoid duplication of effort as a result of DOT's responsibilities under the acts mentioned above and the Department of Interior's responsibilities under the OCS Lands Act, the two agencies signed a Memorandum of Understanding on May 6, 1976, by which DOT was signed responsibility for regulating the design, construction, operation, and maintenance of offshore pipelines to the shore from the outlet flange at (a) each facility where hydrocarbons are produced, or (b) each facility where produced hydrocarbons are first separated, dehydrated, or otherwise processed, whichever facility is farther downstream. DOI was given comparable responsibility for offshore pipelines extending upstream from this dividing point. DOI also agreed to condition any rights-of-way or easements issued by DOI for OCS pipelines upon compliance with the applicable DOT regulations.

The Department of Transportation also has the responsibility to inspect annually all pipelines on federal lands.

4.4.2 Department of Interior

In addition to the jurisdiction mentioned above, DOI regulates the design, construction, and operation of all offshore pipelines through conditions attached to the right-of-way grant, lease stipulations, and OCS Orders.

Included among the requirements which a right-of-way applicant accepts as a condition of the grant is the requirement that the pipeline must be constructed with "the best available and safest technology...which the Secretary determines to be economically feasible" (43 C.F.R. §3340.1). Also, the pipeline must be maintained in such a manner that it will not pose an unreasonable obstruction to fishing and shipping operations.

There are several stipulations attached to leases from Sale 56 which are relevant to pipeline design, construction, and operation. Stipulations 1 (cultural resources), 2 (hard bottom areas), and 7 (unstable sediments) were all mentioned in Section 4.3.1. Stipulation 9, in addition to the conditions established for choosing pipeline or tanker transportation, requires that all pipelines, where feasible, "shall be buried to a depth suitable for adequate protection from water currents, sand waves, storm scouring, fisheries trawling gear, and other uses as determined on a case-by-case basis." The MMS has written several OCS Orders which are designed to supplement existing regulations on drilling and producing operations. OCS Order Number 9 establishes approval procedures for pipelines of leaseholders (primarily gathering lines) and requires certain features and contingencies to be incorporated in the design of these lines.

4.4.3. Coast Guard

Although the operation of offshore pipelines has been specifically excluded from Coast Guard jurisdiction (33 C.F.R. §140.05), the Coast Guard has been given responsibility for the prevention and cleanup of oil discharges from pipelines. The Coast Guard also administers the Offshore Oilspill Pollution Fund, authorized by the OCS Lands Act, which provides money for cleanup costs and damages from spills originating at OCS offshore facilities or surface vessels transporting oil from an offshore facility.

4.4.4. Federal Energy Regulatory Commission

As previously discussed, a pipeline constructed from the OCS to onshore is considered an interstate pipeline. The Federal Energy Regulatory Commission regulates the rates and charges which may be received by pipeline companies in connection with the transportation by interstate pipeline of oil and gas. The commission requires the filing of rate schedules and has the authority to correct any rates deemed unfair.

V. SITING CONSIDERATIONS IN COASTAL NORTH CAROLINA

The major purpose of this report, and the focus of the next four chapters, is to accomplish two basic objectives:

1) To present information on the likely impacts and conflicts that may arise if pipelines are built through coastal North Carolina. Thompson (1981), in recognizing that tradeoffs must frequently be made among unlike resources during utility corridor siting, suggests that such tradeoff decisions should focus on three parameters for each resource and each segment of the landscape involved. These are: (a) the relative importance of the resource affected, (b) the relative magnitude of the impact to that resource (which, since it usually cannot be predicted accurately, must be dealt with in terms of "impact risk"), and (c) the relative degree to which impacts can be mitigated. This is a basic, straightforward approach and provides the underlying framework for the analyses and recommendations of the next four chapters.

2) On the basis of this information, to recommend, from a public perspective, where pipelines should or should not be allowed, or in other words, to recommend criteria for siting pipelines which would minimize overall environmental and economic costs and, hopefully, achieve near-optimal location decisions.

There are several major groups of considerations involved in siting pipelines to protect public interestsIn Chapter VI and Subchapter 9.1 the various factors that might threaten the integrity of the pipeline, causing leaks and ruptures, are addressed. Chapters VII, VIII, and the remainder of IX are concerned with the impacts of pipeline installation and normal operations, and the location of resources sensitive to these activities. A final set of considerations involving the location of resources that might be damaged by the spilled contents of pipelines are mentioned briefly in Section 9.1, and references are made to the extensive literature on this subject.

A secondary objective of this project has been to locate and describe sources of map data for the various features discussed in the text to provide direction to government agencies, pipeline companies, and citizen groups regarding the most up-to-date information available. In the following chapters, these sources are either mentioned within the body of the text or described briefly at the end of sections under the title "Sources." In addition to these specific references, there are several large mapping projects, covering a wide variety of features, of which the interested reader should be aware. Three projects in this category are: (1) East Carolina University's recently completed map study of the peninsula between Albemarle and Pamlico Sounds; (2) the Land Resources Information Service's (LRIS) Submerged Lands project covering the inland waters of North Carolina's coastal zone; and (3) LRIS's mapping effort of Carteret County, the first phase of which has been completed. Agencies or firms wishing to evaluate the suitability of these areas for pipelines would benefit from consultation with these sources.

VI. GEOPHYSICAL HAZARDS AND TECHNICAL CONSTRAINTS ON PIPELINE ROUTING

6.1 GEOLOGY

6.1.1 Introduction

The physical character of the seafloor upon which a pipeline is to be laid is a major factor in determining the cost and difficulty of offshore construction (Gowen et al., 1980). The main considerations are topography, substrate composition, and stability. In addition, certain geological processes, such as earthquake activity and sediment motion, pose threats to the integrity of a pipeline during its period of operation.

The continental shelf off North Carolina has been the subject of extensive, large-scale geologic studies, and much has been learned in recent years about the subsurface structure and stratigraphy, sediment types and distribution, and surface physiography. Reviews of past work and relatively complete bibliographies are available in Zeigler and Patton (1974), Riggs and O'Conner (1975), Henry and Giles (1979), and Riggs (1979). Research on the Carolina shelf and slope is being conducted by federal (BLM, USGS, NOAA, NSF), state (University of North Carolina) and private (Duke University, Chevron Oil Co.) organizations. Many of these research efforts are expected to result in publications in the near future. In the meantime, available literature, progress reports, and frequent contact with investigators are required to obtain and update geologic information.

Certain aspects of the marine geology of the North Carolina continental shelf have been summarized by Riggs (1979), and the review presented here essentially follows his treatment of the subject.

The North Carolina continental shelf is exposed along its length to varying conditions of waves, winds, and sediment input. It is convenient, therefore, to separate the region into three provinces according to the active processes in each. The northern province, the Hatteras Embayment (Figure 6-1), has a relatively narrow and steep continental shelf. The shelf is only about 33 kilometers wide off of Cape Hatteras and widens both to north and south. Toward the north, the shelf is relatively uniformly covered with sediment with irregular topography produced by an extensive sequence of large north-south trending sand ridges. These ridges, with relief of some 10 meters from crest to trough, have smaller transverse sand waves of 2 to 5 meters relief upon their crests (Swift et al., 1978). The latter features, which trend northeast-southwest, have been observed by divers and are known to be actively migrating toward the south, particularly in response to northeast storms which occur during all but the low-energy summer season. The inner shelf region studied by Swift et al. (1978) is subject to sediment motion during a considerable portion of the year.

Raleigh Bay, between Cape Hatteras and Cape Lookout, is a transitional shelf area between the narrow, sediment-laden Hatteras Embayment and the shallow, wide, rock-dominated Onslow Bay to the south. No studies were found which described the geology of this region. The maps of Newton et al. (1971) provide the large-scale sediment distribution, but do not show sand wave fields and outcrops which are known to be abundant in some areas.

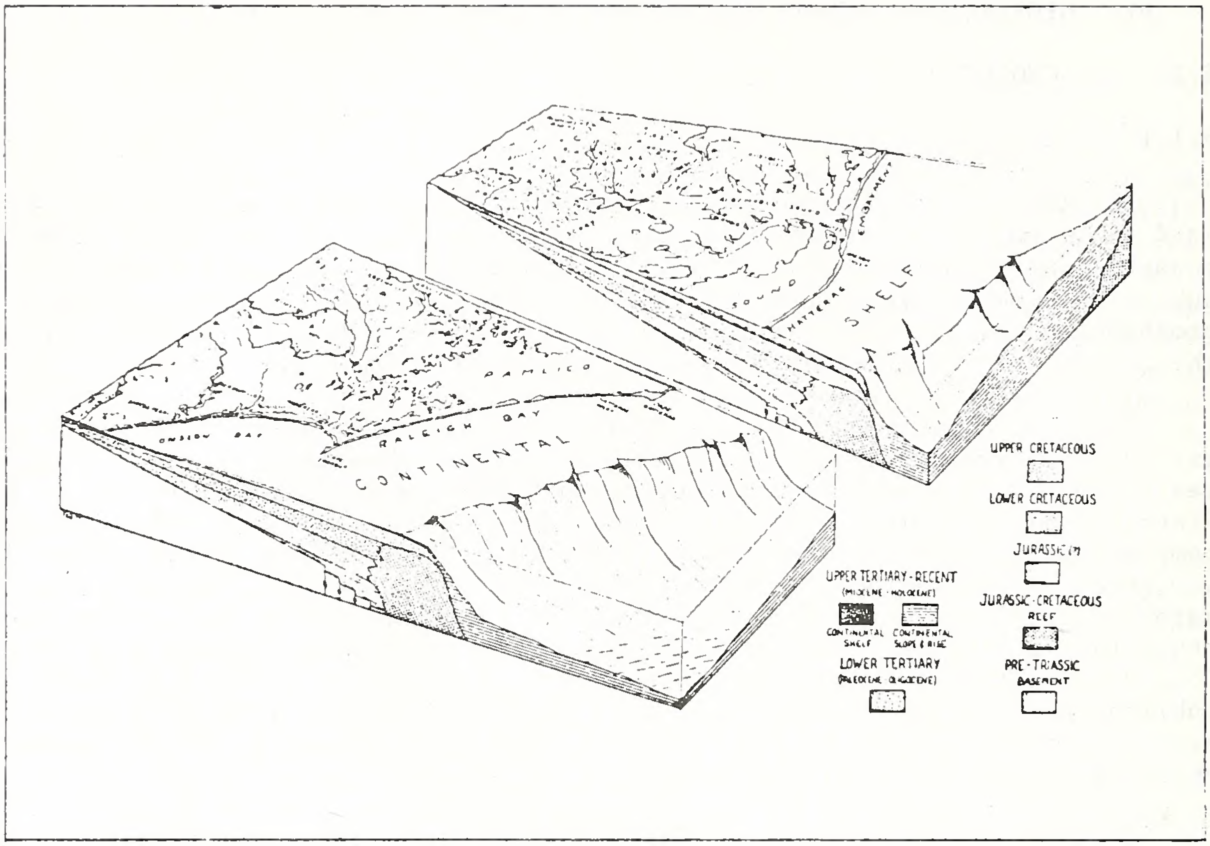


Figure 6-1. Block diagram of the coastal plain and continental shelf of North Carolina showing the generalized stratigraphic framework. (from Riggs, 1979)

Onslow Bay extends in a broad arc westward from Cape Lookout and Shackleford Bank to Cape Fear. The generally south and southeast facing embayment responds to a different and generally lower energy regime than Raleigh Bay or the Hatteras Embayment. The shelf region is relatively shallow and broad with little sediment supply. It is consequently dominated by reefs, hard bottoms, and rock outcrops. There are no studies available of the detailed sediment structure, distribution, and dynamics of the OCS region. The inner shelf, however, has been described in a series of regional studies in the vicinity of Bogue Banks (Mixon and Pilkey, 1976), New River Inlet (Crowson and Riggs, 1976), southern Onslow Bay (Riggs and Freas, 1967), and Fort Fisher (Moorefield, 1977). These studies indicate that the inner shelf region is an area of frequent rock outcrops and variable sediment cover. Rock scarps with relief as great as 5 meters are reported (Crowson and Riggs, 1976), and sediment transport is active over much of the year as evidenced by sand waves and ripples. A traverse of southern Onslow Bay, for instance, is characterized by ridge and swale topography in the nearshore zone to a depth of about 15 meters (trough depth). These undulations have relief of 5 meters and are 185 meters to 520 meters in length. Seaward of these features, the bottom slopes gently seaward at roughly one meter per mile until interrupted by an abrupt 5-meter rock ledge at about 20 meter water depth.

An extensive layer of phoshporite sands of unknown thickness has been reported in Onslow Bay. This appears to be an economically exploitable resource of large magnitude along nearly the entire length of the bay.

Sub-bottom geological structures do not affect pipeline construction and operation unless hard bottom, rock outcrops, or active surface faults are found in the region. Diapiric structures, located in deep water seaward of the shelf edge southeast of Cape Hatteras, have been reported by Grow et al. (1977). An extension fault, possibly caused by diapiric growth, has been mapped by the USGS near the 200 meter isobath southeast of Cape Fear (Ball et al., 1979). These are expected to be extremely slow growing features.

6.1.2 Bottom Topography

While pipeline technology is such that almost any type of topography can be traversed, certain types of topography present more problems than others (Rooney-Char and Ayres, 1978). A gradually sloping soft bottom is generally preferred. Ideally, the seafloor topography between platform and landfall should have a slope of less than 10 percent, be free of deep trenches and ridges, and have a surface free of irregularities such as reefs and large bedforms (Gowen et al., 1980). During analysis of potential pipeline corridors, existing bathymetric surveys provide general information which may be used to include or exclude large areas of seafloor from consideration. In the final design analysis, however, a detailed survey along the proposed route is necessary.

The bathymetry of the continental shelf off the Carolinas has been charted during numerous investigations (e.g. Newton and Pilkey, 1969; Macintyre and Milliman, 1970). The Duke University Cooperative Oceanographic Program has been responsible for many intensive investigations of the Carolinas' continental margin and has acquired abundant bathymetric data; a summary of these data, inclusive through the late 1960's, may be found in Newton et al., 1971.

More detailed contouring of bathymetric data is available from the National Ocean Survey (NOS), which produces bathymetric charts at a scale of 1:250,000 to correspond to the U.S. Geological Survey topographic sheets of the same scale. Many offshore areas around the U.S. have been charted by NOS in this map series, but not all are available at present. Figure 6-2 is an index to charts which cover the Carolinas' continental margin, and a listing of the charts is provided in Table 6-1.

The National Geophysical and Solar-Terrestrial Data Center (NGSDC) in Boulder, Colorado, is a third source of bathymetric data. NGSDC acts as a repository for data collected by numerous other agencies. The data are stored in digital form and are available on magnetic tape at cost. Arrangements may also be made to have specific data sets plotted.

As part of a program to automate nautical chart production, sounding data for one-degree square areas around the U.S. coast have been digitalized by NGSDC. Most of the data presently available for the Carolina coast date from surveys conducted in the 1950's and 1960's, though some are as recent as 1975 (Konrad, 1982). Areas of digital hydrographic data presently available are shown on the index map in Figure 6-2.

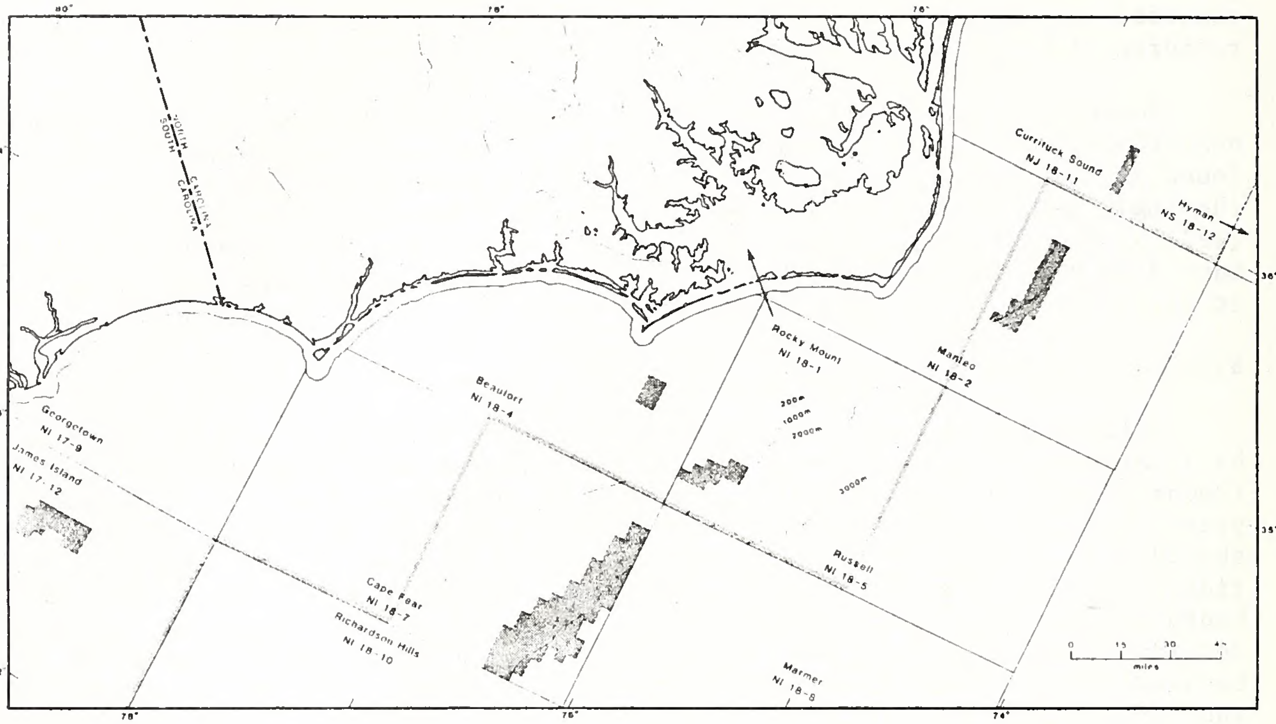


Figure 6-2. Index to the National Ocean Survey/U.S. Geological Survey bathymetric charts of the Carolina continental margin.

Map Name	Number	Status
North Carolina	0806N-23	Published 1972, superceded
Currituck Sound	NJ 18-11	Published 1978
Hyman	NJ 18-12	In prep.; prelim. copies avail.
Rocky Mount	NI 18-1	In prep.
Manteo	NI 18-2	In prep.
Beaufort	NI 18-4	Published 1972
Russell	NI 18-5	In prep.; prelim. copies avail.
Georgetown	NI 17-9	Published 1978
Cape Fear	NI 18-7	Published 1978
Marmer	NI 18-8	In prep.; prelim. copies avail.

Table 6-1. Status of NOS/USGS Bathymetric Maps at a Scale of 1:250,000 as of December, 1980.

Analysis of this data shows that seafloor topography off North Carolina is characterized by slopes generally less than 10 percent in the regions between Sale 56 lease areas and potential landfalls, although there are numerous local exceptions. There are no major bathymetric features which cannot be avoided by a pipeline corridor. Two adverse areas for pipelines are the shoals off Cape Fear and Cape Lookout, where strong currents and shifting sediment are common. Abundant irregularities are apparent on USGS 1:250,000 contour maps with a contour interval of 2 meters. There is an area northeast of Cape Fear which is similar to "scabland" topography and where pipeline construction could be very difficult, depending on the degree of induration of the material.

6.1.3 Rock Outcrops and Hard Bottom

A significant portion of the North Carolina shelf is characterized by a lack of sediment cover. Riggs (1979) presents a sketch map of areas of rock outcrops (Figure 6-3), but notes that the exact locations and extent of the areas are known only vaguely. In addition, presently available maps do not describe the rock types or degree of induration of substrate devoid of unconsolidated sediment. Two sources of data may eventually be used to map these hard grounds with a fair degree of accuracy. One of the by-products of a series of research cruises funded by NSF to examine the phosphorites system of the Atlantic continental margin will be a substantial amount of data that can be interpreted for the presence of hardgrounds (Riggs, 1982). In addition, a project may be funded in the near future to map hard grounds off North Carolina using data gathered by the Division of Marine Fisheries' research vessel Dan Moore on the location of untrawlable areas (Smith, 1982).

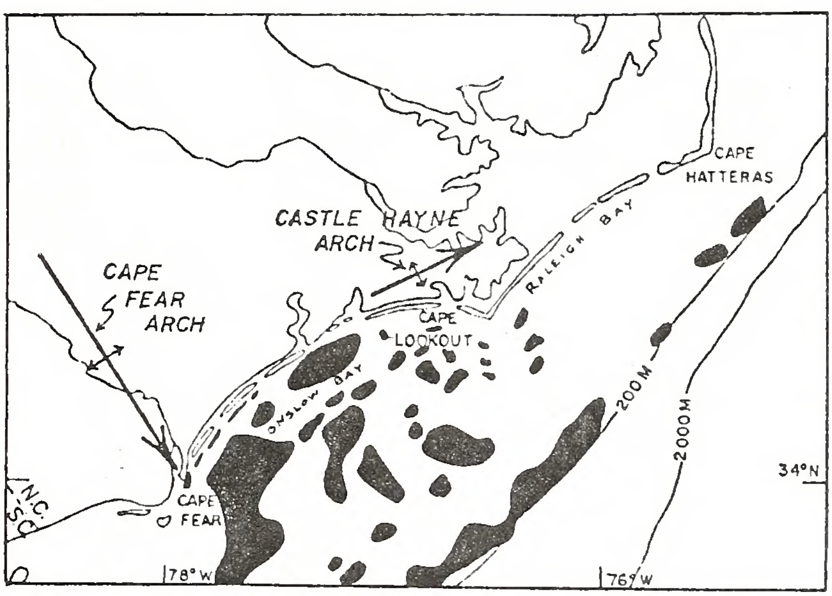


Figure 6-3. Generalized map of eastern North Carolina showing the basic structural framework and the general distribution of known rock outcrops on the continental shelf. (from Riggs, 1979)

An additional compilation of data on rock outcrops has been made by Orrin Pilkey (University of North Carolina) and Ian Macintyre (Smithsonian). It is unpublished and probably largely superceded by the new data mentioned in the previous paragraph. In any event, if it cannot be used to estimate the areal extent of rock outcrops, it does corroborate the fact that they are numerous.

Though many studies of the marine geology of the North Carolina shelf and shoreline have been conducted or are underway, more detailed information is necessary for pipeline route planning. There are abundant rock outcrops, reefs, ledges, and hard bottoms along the southern half of the study area, south of Cape Hatteras. The area is not yet thoroughly charted, however, and recent studies have shown that what were previously thought to be isolated outcrops are, in fact, continuous reef ledges of considerable length.

6.1.4 Sediment Characteristics

The type of sediment most preferred for pipeline installation is sand-sized material exhibiting low compaction and cementation, homogeneous in its textural characteristics over large areas, and in equilibrium with hydrodynamic forces caused by waves and currents. The least desirable sedimentary deposits are highly compacted clay- and silt-sized materials, and coarse-grained gravels and boulders. In these latter deposits, trenching becomes more difficult and considerably more expensive.

In general, the distribution of unconsolidated sediment, where present, varies from predominantly sand-sized material over most of the shelf, to silty-sand and clayey-silt farther offshore on the slope (Hollister, 1973). The sediment map from the Oceanographic Atlas of North Carolina (Newton et al., 1971) portrays the general distribution of unconsolidated material on the shelf.

The thickness of sedimentary cover is an important parameter to be considered in routing pipelines if they are to be entrenched. A minimum of two meters of sediment is considered acceptable (Nothdurft, 1980). Maps showing thickness of sedimentary cover are not available, although it may be possible to construct them using existing data from high resolution seismic profiling surveys (used by oil companies during exploration) or bathymetric surveys. In any event, detailed surveys of this nature are conducted by pipeline engineers as part of the final route selection process.

Certain geotechnical characteristics of sediment may pose a hazard to seafloor pipelines. The parameters involved relate to the bearing strength of the sediment and its liquefaction potential (i.e., how susceptible the sediment is to behaving like a liquid). Low bearing strength may result in hazardous bending stresses if the pipeline sinks more deeply into the sediment than was intended by designers. Liquefaction of enclosing sediment can also result in bending stresses on the pipeline and cause flotation of the pipeline out of its backfill. The geotechnical properties of the surrounding sediment and the expected properties of backfill covering the pipe are major concerns to designing engineers (Funge et al., 1977).

The liquefaction potential of unconsolidated material used for foundation support has been the subject of numerous studies (e.g., Youd, 1978). When liquefaction occurs, the sediment experiences a rapid loss of bearing strength

and behaves more like a liquid than a solid. Sediment most susceptible to liquefaction is typically sandy, porous, and high in water content and interstitial gases. Triggering mechanisms include ground shaking induced by earthquakes and hydrostatic pumping caused by waves. The latter generating process is the more likely on the North Carolina shelf.

If a trench is dug for the pipeline, the backfill would be more susceptible to liquefaction than the enclosing sediment. This could expose the pipeline to the risk of floating out of the trench if not adequately ballasted (Gowen et al., 1980). Pipeline designers predict the liquefaction potential of backfill and specify the amount of anchoring needed to ensure that a pipeline will remain in the trench if liquefaction occurs.

6.1.5 Seafloor Instability

Certain unconsolidated sediments are prone to mass movements such as slumps, debris slides, and mudflows, or to sediment transport involving erosion and deposition. Such unstable sediments create several dangers for pipelines, including high bending stresses and even rupture as a result of dislocation, spanning, and abrasion of pipeline coatings and metal surfaces.

Designers and engineers attempt to minimize these safety hazards by careful route selection, use of proper amounts of ballasting or careful anchoring techniques, and by application of protective coatings of concrete. However, pipeline breaks have occurred in the past due to over-stressing the line as a result of seafloor instability problems (Funge et al., 1977).

Rapid erosion and deposition of sediment, and movement of sediment bedforms, occur on the North Carolina shelf. No data are presently available to accurately depict these phenomena on maps, but sand waves are known to be present off Cape Lookout and Cape Fear (Figure 6-4). These active bedforms have also been observed in satellite imagery of the region.

Sand waves have been mapped and are known to be actively moving features, particularly during the more energetic times of year (Swift et al., 1978). Their motion may be caused by both waves and unidirectional currents and is evidently toward the south. The movement of sand waves is an erosion process which may expose pipelines, causing spanning, abrasion, and other undesirable effects. Studies have shown that even the largest of these bedforms migrate. The rate of migration and its relationship to wave and current conditions are unknown.

Mass movement of sediment such as slumps or slides could also remove pipeline support or, in extreme cases, actually carry away portions of the line. Slump scars were identified near the shelf break in the mid-Atlantic region in the vicinity of Wilmington Canyon. However, later side scan sonar observations indicated that these features may be related to the relict drainage pattern which developed during lower stands of sea level, and do not pose a hazard to OCS development.

Mudflows are another form of instability that have damaged pipelines in the Gulf of Mexico (USDOI/BLM, 1981c), particularly on the Mississippi River Delta. They are a phenomenon associated with rapid accumulation of

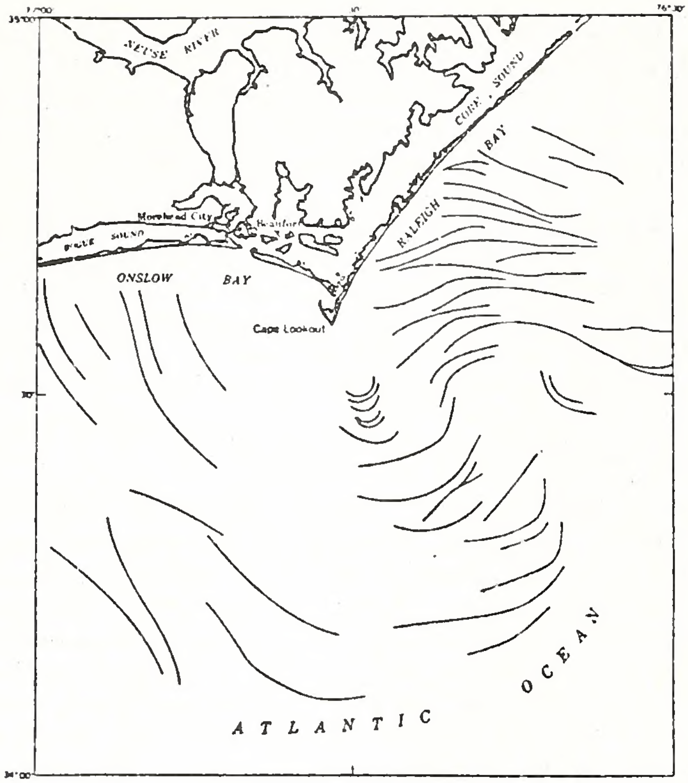


Figure 6-4. Submerged topographic sand ridges in the Bogue Banks area. (from Riggs, 1979)

fine-grained sediment (i.e., deltaic environments) and are not known to occur on the North Carolina OCS.

The physical presence of an unburied pipeline may induce sediment transport away from the pipeline, a process referred to as scour. The design problems that scour presents are two-fold: the mechanics of the process are poorly understood, so that designers cannot predict its presence until after the line is installed (Funge et al., 1977), and the bottom currents which create scour (such as those induced by severe storms) may be highly variable in time and space, making them unpredictable as well. Scour may cause spanning between solid points of the foundations, ultimately creating bending stress in the pipe. Scour may also remove backfill from an entrenched pipeline, exposing it to the risk of flotation (Manley and Herbich, 1976).

Scour is most likely to occur in unconsolidated, fine sand-size sediment (USDOI/BLM, 1981b) and is less likely in sediments dominated by coarse sand and gravel, clay, or silt. Large areas of the North Carolina shelf are covered by loose sediment susceptible to scour, and the occurrence of severe storms, with their attendant large waves and induced bottom currents, may contribute to scour around pipelines.

6.1.6 Tectonic Activity

In spite of the destructive potential of earthquakes, tectonic activity ranks as a "least probable" potential hazard to submarine pipelines (Funge et al., 1977). Where present, however, tectonic activity does present hazards to pipeline integrity in several forms: horizontal and vertical displacement along faults, ground shaking, liquefaction and differential settling of foundation materials, submarine slumps and slides, and tsunamis (large sea waves associated with offshore earthquakes).

A certain amount of protection against earthquake damage can be included in the design of the pipeline. Sufficient ballast and anchoring will lessen the chance for damage due to flotation and liquefaction. Additional flexibility can be built into sections crossing active faults (Funge et al., 1977), and the pipeline should not be entrenched in these zones.

The region offshore of North Carolina is not known to be seismically active, and it is unlikely that earthquake activity will become a constraint to pipeline construction. Seismic risk maps produced by the U.S. Geological Survey (Figures 6-5, 6-6) reveal that damaging earthquakes in North Carolina (and presumably offshore as well) are unlikely. However, such risk studies are based largely on historical records, and earthquakes registered by seismometers and in newspaper accounts may not be truly representative of tectonic activity in the region. The time period for which we have earthquake records is short compared to the time scales on which tectonic processes occur.

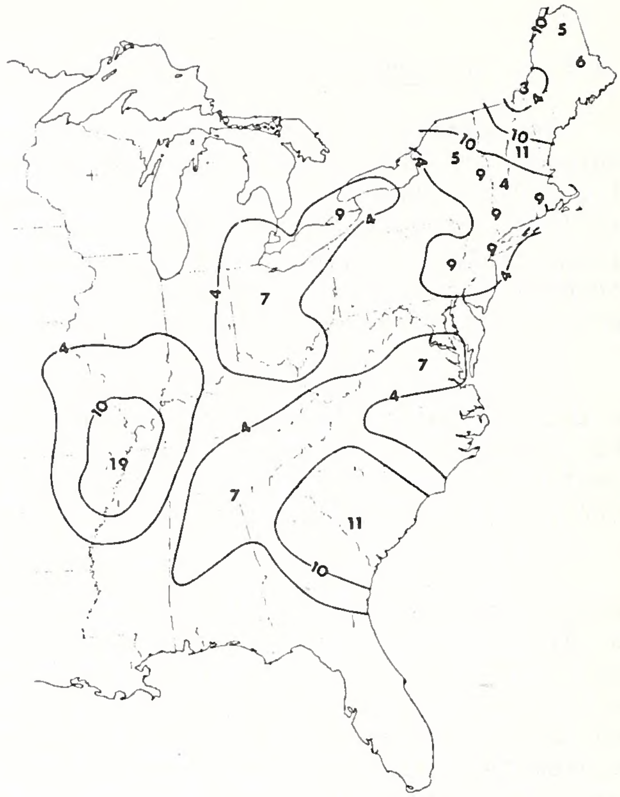
The nearest recorded earthquake which did cause damage occurred in the vicinity of Charleston, South Carolina, in 1886. This earthquake affected an area with a radius of 800 miles and produced strong ground shaking out to about 100 miles (Coffman and von Hake, 1973). The distance from the Charleston area to the lease areas on the North Carolina shelf is on the order of 300 to 400 miles.

The Wilmington, North Carolina, area also has experienced tremors and earthquake activity. These have been manifested in booming noises, rattled objects in homes, and small seiches in Southport harbor (Stewart et al., 1975; Stewart and Taylor, 1976; Taylor, 1977). The possibility of a destructive earthquake in this region has been proposed by several investigators (Henry and Giles, 1979; Scholz et al., 1973; Kisslinger, 1974). There is also evidence that crustal movements are occurring on the southeastern U.S. coastal plain (Cronin, 1981) and that the Hatteras Embayment and Cape Fear Arch are active tectonic structures which may show increased seismic activty in the future (Benton, 1982).

6.1.7 Inlet Migration

North Carolina's coastal inlets (Figure 6-7) are dynamic zones through which water is exchanged in response to variations in sea level and runoff. They provide access to the coastal wetlands, bays, and interior for recreation, commerce, and fisheries and are vital to the economic and ecological well-being of the coastal zone. Currents in and around the inlets are caused primarily by tides which transport water, sediment, nutrients, and biological organisms through the channels. The inlets shift due to prevailing

Figure 6-5. Preliminary map of horizontal acceleration (expressed as percent of gravity) in rock with 90 percent probability of not being exceeded in 50 years. (from Algermissen and Perkins, 1976)



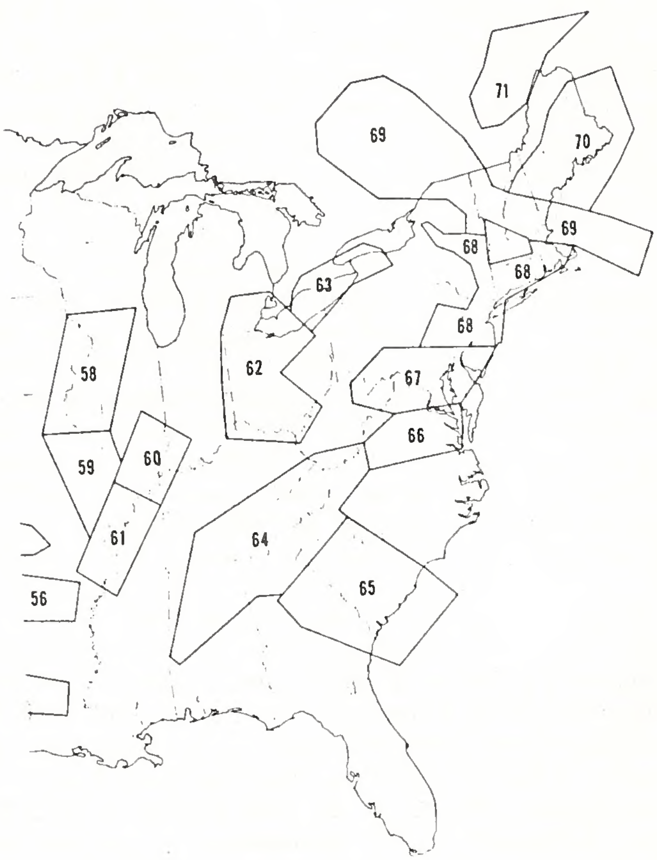


Figure 6-6. Seismic source areas. (from Algermissen and Perkins, 1976)

ZONE NO.	NUMBER OF MODIFIED MERCALLI MAXIMUM INTENSITY V's/100 YRS*	ESTIMATED MAXIMUM INTENSITY	ESTIMATED MAXIMUM MAGNITUDE
64	54.4	VIII	6.1
65	19.9	X	7.3
66	13.0	VIII	6.1
67	7.8	VII	5.5

* Intensity V:
Felt by nearly everyone; many awakened. Some dishes, windows, etc., broken; a few instances of cracked plaster; unstable objects overturned. Disturbance of trees, poles, and other tall objects sometimes noticed. Pendulum clocks may stop.

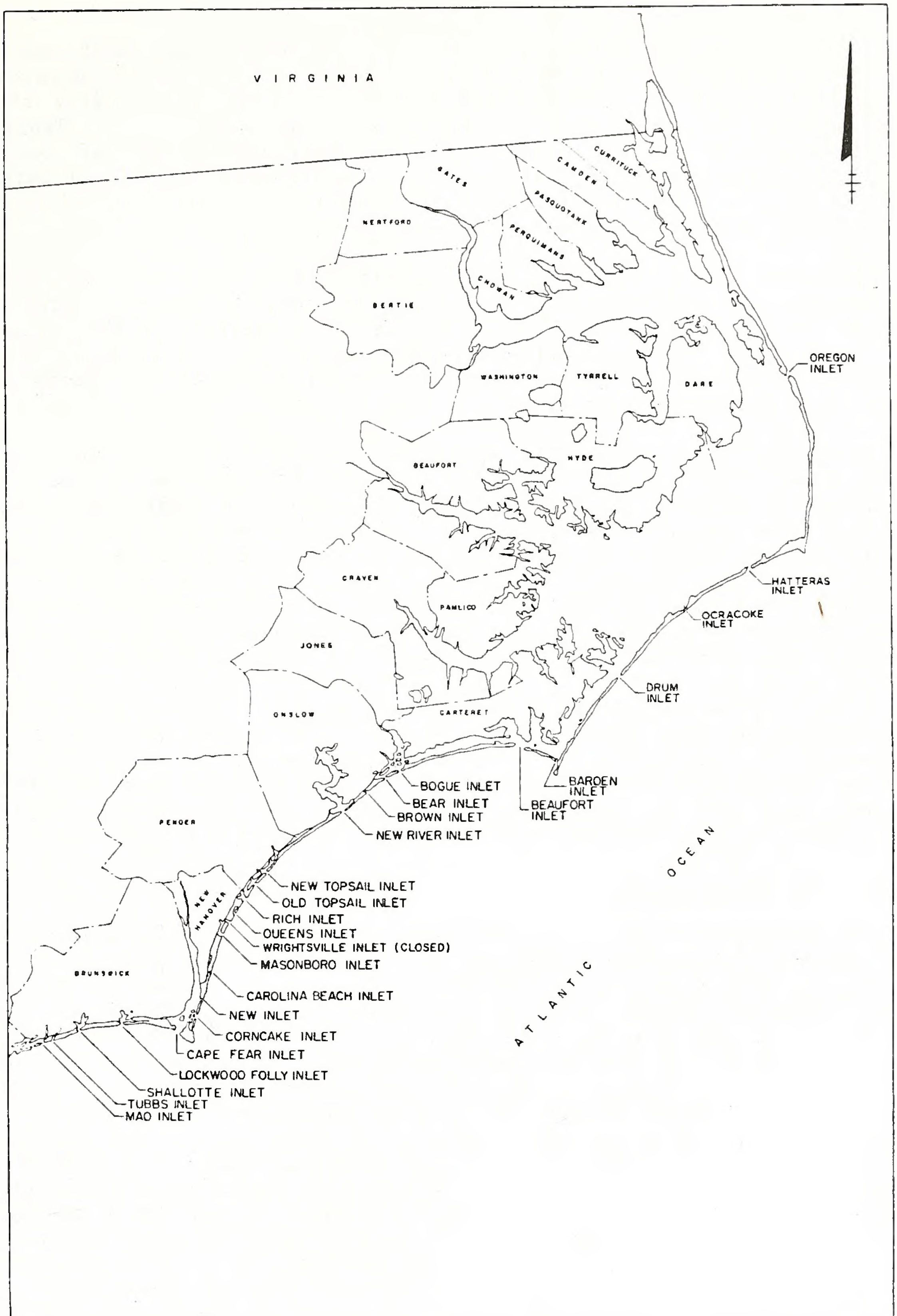


Figure 6-7. Location of North Carolina's inlets. (from Baker, 1977)

winds and currents and, during periods of major storms, new inlets may form while others may close. As a result of commercial and residential development on the barrier islands, some of the inlets have been artificially filled, while attempts are being made to dredge and stabilize others. Table 6-2 identifies several of the inlets which have been the subject of extensive biological, circulation, or sediment transport studies. Additional data and study results for other selected inlets are available upon request at the U.S. Army Engineer District, Wilmington, N.C.

Obviously, the migration of coastal inlets is an important consideration for pipeline landfall selection on barrier islands. These inlets are among the most dynamic regions along the shoreline, and pipelines in their vicinity may be exposed and destroyed during the course of migration. Coastal protection measures or the presence of structures does not guarantee a controllable pattern of migration.

Reviews of inlet migration have been conducted by Langfelder et al. (1974), Baker (1977), and Priddy and Carroway (1978). These works show that the majority of the inlets exhibit a north-south or east-west migration pattern. Some oscillate with no set long-term trend, and others appear stable, usually because of the addition of protective work or because of periodic dredging. The migratory characteristics of most of North Carolina's inlets are summarized in Table 6-3. Note that of the seven relatively stable inlets (Shallotte, Lockwood Folly, Cape Fear, Masonboro, Bear, Beaufort and Ocracoke), four are maintained to some degree by dredging or protective works.

In view of the migratory characteristics of inlets and the fact that they attain relatively high (several knots) currents, pipelines should avoid these openings in the barrier island system. A spill in the vicinity of an inlet might be transported into the estuary system and would be very difficult to contain. As a general rule, pipeline landfalls should be located well away from inlets and in a direction opposite any established migratory trends.

6.1.8 Coastal Erosion

Preferred areas for pipeline landfalls will be dictated to some degree by beach stability. Studies examining beach erosion along the entire North Carolina coast have been completed by Langfelder et al. (1968), Wahls (1973), and Dr. Spencer Rogers (1982). The North Carolina Office of Coastal Management, and in part in cooperation with R. Dolan at the University of Virginia, is presently updating these beach erosion rates, and a report should be available in late 1982. Smaller studies designed to determine the erosion rates of specific North Carolina beaches are available through the U.S. Army Engineer District in Wilmington. Examples of these reports are the Manteo, Shallowbag Bay studies and the Long Beach, Yaupon Beach studies (U.S. Army Corps of Engineers, 1973). Other design memoranda also exist. Recent studies of Wrightsville Beach and Holden Beach have been completed for the Coastal Engineering Research Center (CERC) of the U.S. Army Corps of Engineers by Winton et al. (1981) and Miller (1981), respectively.

Figure 6-8 from Langfelder (1971) summarizes the findings of Langfelder et al.'s (1968) analysis of photographs collected between 1938 and 1966. The least erosive combined areas of dune line and high water line, from north to south, are in the vicinities of Duck, Cape Lookout, Bear Inlet, Topsail Beach,

Inlet Name	Reference
Oregon Inlet	Jarett, 1978
	Singer and Knowles, 1975
Drum Inlet	Blankenship, 1976
Barden Inlet	U.S. Army Corps of Engineers, 1978
Beaufort Inlet	U.S. Army Corps of Engineers, 1976
New River Inlet	Schwartz and Musialowski, 1978, 1980
	Hobson, 1978
	Hobson and James, 1979
Masonboro Inlet	Harris and Bodine, 1977
	Escoffier, 1977
	Amein, 1973
Carolina Beach Inlet	Gopalakrishnan and Machemehl, 1978
	U.S. Army Corps of Engineers, 1970
Lockwoods Folly Inlet	Machemehl, Chambers and Bird, 1977

Table 6-2. Detailed studies conducted on selected North Carolina coastal inlets.

Masonboro Island, Ocean Isle Beach, and Sunset Beach. An updating of these same areas to 1972 by Wahls (1973) found the same trends in all areas except near Cape Lookout, where greater erosion was observed at the high water line. The accretion rates had increased substantially near Mad Inlet, and accretion was also detected at Avon and Frisco on Hatteras Island, the northern end of Portsmouth Island near Ocracoke Inlet, New Topsail Beach, and Yaupon Beach. Further updating of these trends will be possible when the data scheduled for release in 1982 become available.

Erosion rate studies at potential landfall sites should be initiated as soon as possible to obtain an extended record of beach variability in response to storms, seasons, and long-term factors. Few detailed studies presently exist, and only two (Winton et al., 1981, and Miller, 1981) provide information on the beach profile "sweep zone". This is the zone between the highest and lowest measured sand levels at the beach profile site and must be known to determine the design depth of burial for the pipeline.

Table 6-3. North Carolina inlet migration trends summarized from Langfelder et al. (1974) and Priddy and Carraway (1978).

Inlet	Migration
Mad	Westerly and narrowing since 1960
Tubbs	Easterly and widening since artificially closed and reopened in 1970
Shallotte	Slight east-west oscillation (no trend)
Lockwood Folly	Rather stable (maintained by dredging)
Cape Fear	Almost negligible (maintained by dredging)
Corncake	Southwesterly (now closed)
New	Southerly (this inlet has experienced greatest migration of 467 ft/yr over 30 years)
Carolina Beach	Northerly (23 ft/yr)
Masonboro	Stable (because of jetty)
Queens	Southerly
Rich	Southerly (38 ft/yr)
Old Topsail	Southerly
New Topsail	Southerly (greater than 25 ft/yr)
New River	Southerly and widening (maintained by dredging)
Browns	Southerly (29 ft/yr)
Bear	Slight north-south oscillation (no trend)
Bogue	Easterly (large short-term variations)
Beaufort	Stable (because of protective work and dredging)
Bardens	Widening to the east
Drum	Widening to the northeast since artificial opening in 1971
Ocracoke	Nearly stable with slight migration to southwest
Hatteras	Northeasterly since 1963
Oregon	Southerly (channels must be and are maintained to protect bridge)

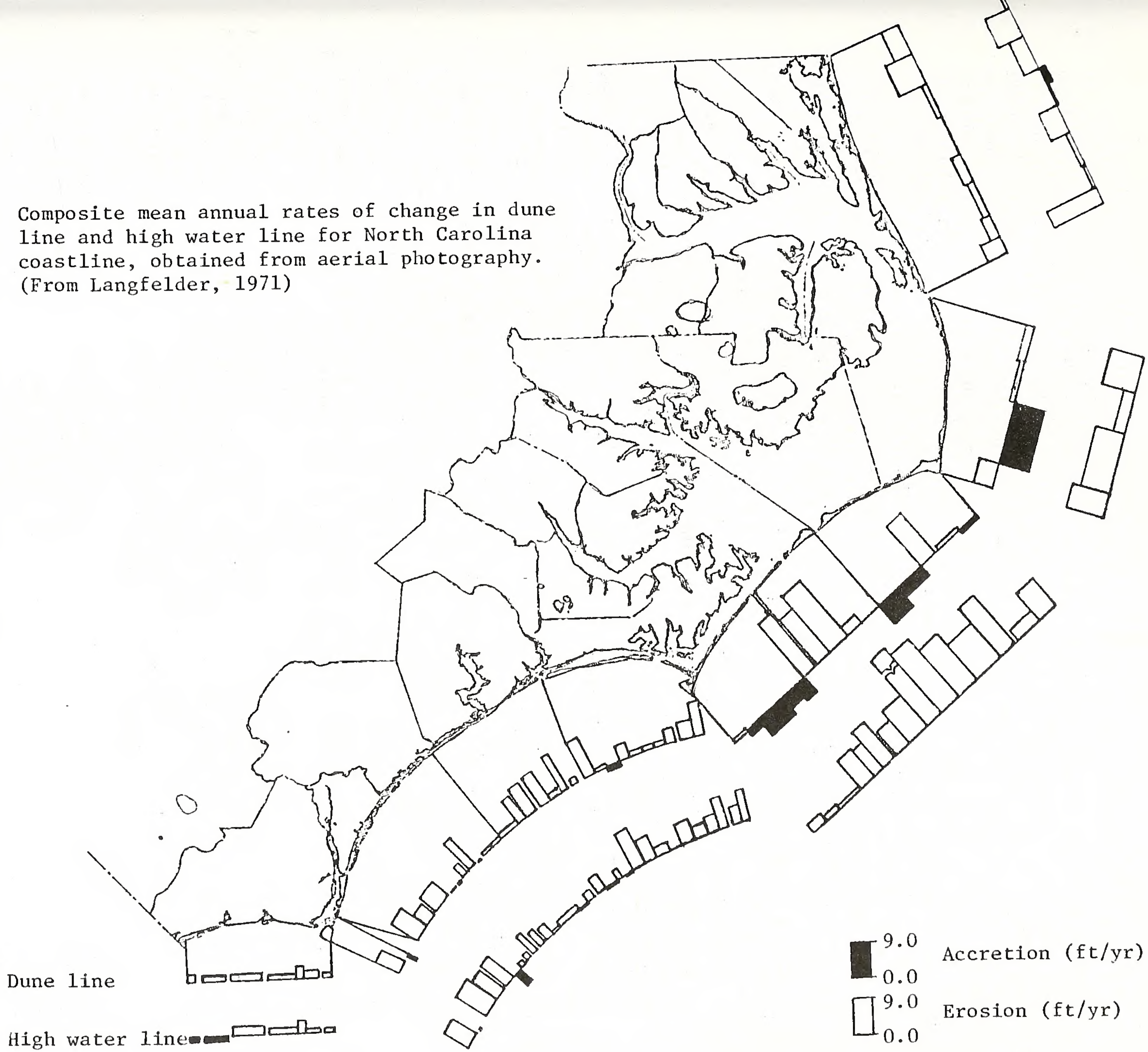


Figure 6-8. Composite mean annual rates of change in dune line and high water line for North Carolina coastline, obtained from aerial photography. (From Langfelder, 1971)

6.2 PHYSICAL OCEANOGRAPHY

6.2.1 Introduction

The energy which causes the ocean to move is derived, ultimately, from the sun and is transferred to the sea by the action of the wind and by actual heating and cooling of the water surface. The wind causes the large ocean currents which are modified and constrained by the earth's rotation and the shape of the ocean basins themselves. Winds blowing across the water surface also create waves, the height and energy of which depend upon the velocity of the wind and the distance over which it has had an opportunity to transfer its energy. The latter distance is known as the fetch. Large storms may create waves that travel great distances across the ocean to arrive at a faraway shore with their energy essentially undiminished. Local winds may also generate waves, known as sea, which superpose their height upon the existing swell. The combination of sea and swell may be considerable, occasionally reaching heights of 40 feet near continental areas. Waves as high as 112 feet have been reliably reported at sea (Bascom, 1980).

North Carolina possesses a dynamic offshore oceanographic regime. South of Cape Hatteras there are three cusp-shaped features (bays) of widths varying from 40 to 110 kilometers out to the shelf break. These are generally less than 50 meters deep, and the circulation is influenced primarily by the winds and tides. Offshore of the shelfbreak, the bottom drops off rapidly to the Blake Plateau (approx. 800 meters) and the Gulf Stream meanders as it flows to the northeast. Between the shelfbreak and the Gulf Stream, cyclonic (counter-clockwise) rotating frontal eddies are observed with frequencies of 2 to 14 days (Lee and Mayer, 1977).

The SW-NE geographic orientation of the three bays is generally conducive to upwelling with southwesterly winds and downwelling with northeasterly winds. The former wind regime is typically observed in July, and the latter in September and October (Weber and Blanton, 1980). In addition, the entire North Carolina coastline is susceptible to the direct effects of hurricanes moving up from the south, having averaged a direct hit or close passage once every four years between 1899 and 1980 (U.S. Department of Commerce/NOAA, 1981).

North of Cape Hatteras the shelf tends to widen again, and the Gulf Stream moves away from the shelf break out into the North Atlantic. Once again, local winds and tides are the primary driving forces for shelf circulation. Offshore, occasionally large anticyclonic (clockwise) rotating warm core Gulf Stream rings move south along the shelf break to Cape Hatteras and are reabsorbed into the Gulf Stream.

The coastline orientation north of Cape Hatteras is to the north and northwest. Here, northwesterly winds which favor downwelling of coastal waters generally prevail from November through March (Weber and Blanton, 1980). In addition, "Northeasters", storms which have a long fetch and are capable of building up large waves as they move across the shelf and into the coastal zone, are common occurrences, frequently buffeting this stretch of coastline.

6.2.2 Currents

Knowledge of the currents in the waters adjacent to North Carolina will be needed at various stages of pipeline planning and construction. In tidal inlets currents may cause scour, sediment transport, and stresses to such an extent that particular areas should be ruled out as acceptable coastal approaches. In the coastal zone and offshore, seasonal patterns of transport will need to be considered to avoid pipeline exposure and structural stress during pipeline construction and operation, and to enable prediction of the transport and fate of pollutants, such as oil, which may be introduced into the water. Also in the coastal zone, the large current shear stresses developed by the back-and-forth motion of the waves will dislodge bottom material and make the sediment available for transport by unidirectional currents that, by themselves, would not cause transport. Further offshore, the influence of a high current and wave regime may be a factor in pipelaying and pipeline safety.

The observed currents associated with various North Carolina inlets are reported in many documented studies by the Corps of Engineers and other investigators (see Table 6-2). Near-surface inlet velocities as high as 150 cm/s have been reported (Singer and Knowles, 1975).

Further offshore, subsurface current meter measurements have been made at various locations across the North Carolina shelf and slope, and in deeper offshore waters, using moored current meters (Figure 6-9). These data have been collected by many different investigators (Table 6-4).

As can be seen in Figure 6-9, Onslow Bay, between Cape Fear and Cape Lookout, has been the most heavily instrumented offshore area. Most of this instrumentation has been under Department of Energy contract to Dr. L. Pietrafesa (N.C. State University) and under National Science Foundation and Office of Naval Research funding to Drs. J. Bane (University of North Carolina, Chapel Hill) and D. Brooks (Texas A&M). All data are accessible through the sources indicated in Table 6-4.

Two hurricanes of significance have passed by the North Carolina coast while moored meters have been in place: "Belle", in August 1976, and "David", in September 1979. Dr. Pietrafesa (1982) noted that higher current velocities were observed in Onslow Bay for the 1976 storm, since the 1979 storm passed inland of the North Carolina coast, having gone ashore at Savannah, Georgia. Pietrafesa found velocities in the 90-120 cm/s range just 4 meters off the bottom in 30 meters of water. Interestingly, Macintyre and Pilkey (1969a) observed small channels in Onslow Bay 30 kilometers from shore, which they hypothesized were formed by a hurricane.

Further offshore in the Gulf Stream, Brooks and Bane (1981) have reported current velocities as high as 134 cm/s at 250 meters depth in 390 meters of water. Twenty meters from the bottom, they reported velocities as high as 53 cm/s.

Surface currents on the shelf and in the Gulf Stream are not typically monitored by moored current meters. Surface drogues, ship drift records, and surface drifter cards are more likely means of measurement. Such data for the North Carolina coast are quite voluminous and have been reviewed and analyzed

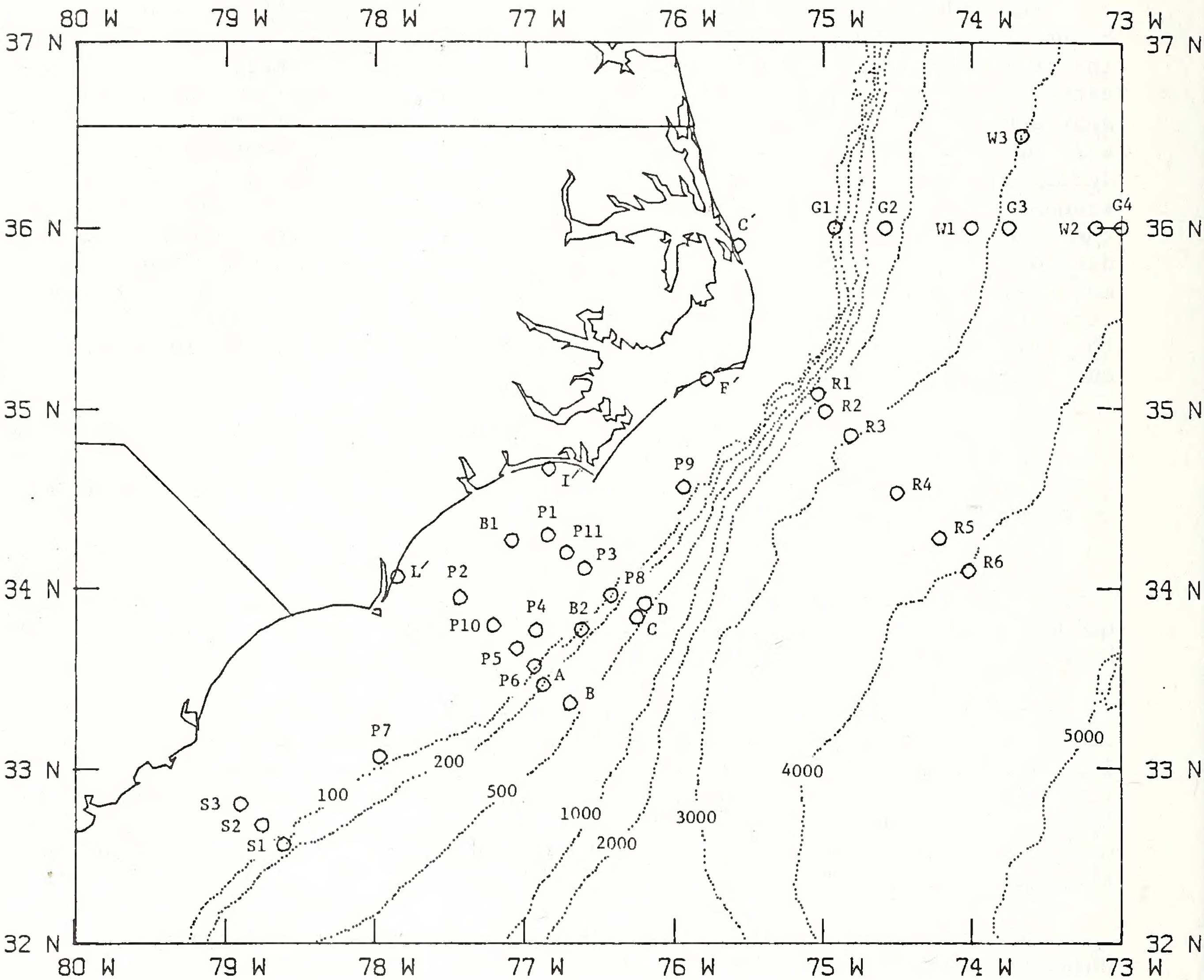


Figure 6-9. Previous locations of current meter moorings on the North Carolina shelf and slope. (See Table 6-4 for explanation)

Table 6-4. Current meter moorings off the North Carolina coast.

Mooring	Approximate Location	Water Depth (m)	Meter Depth (m)	Date	Investigator/ Funding	Investigator's Identification	Reference or Source
B1	34°16'N 77°05'W	28	26	7/23/68- 7/24/68	Blanton/NSF	onshore	Blanton (1971)
B2	33°47'N 76°37'W	52	50	6/25-26/68 7/23-24/68	Blanton/NSF	offshore	Blanton (1971)
R1	35°05'N 75°02'W	1365	1265	5/08/71- 5/26/71	Richardson/ONR	A(84)	Richardson (1974)
R2	34°59'N 74°59'W	2675	2575	5/30/71- 7/23/71	Richardson/ONR	B(93)	Richardson (1974)
R3	34°51'N 74°49'W	2910	2810	5/08/71- 5/26/71	Richardson/ONR	C(86)	Richardson (1974)
R4	34°32'N 74°30'W	3320	3220	5/09/71- 5/27/71	Richardson/ONR	D(88)	Richardson (1974)
R5	34°17'N 74°13'W	3820	3720	5/31/71- 7/22/71	Richardson/ONR	E(94)	Richardson (1974)
R6	34°06'N 74°01'W	4245	4145	5/09/71- 5/31/71	Richardson/ONR	F(90)	Richardson (1974)
P1	34°18'N 76°51'W	30	12 26	8/75-12/75 7/76- 8/76 12/76-4/77	Pietrafesa/DoE	A	L. Pietrafesa, N.C. State Univ.
P2	33°57'N 77°26'W	30	12 26	8/75- 9/75 7/76- 8/76 12/76-4/77	Pietrafesa/DoE	B	L. Pietrafesa, N.C. State Univ.
P3	34°07'N 76°36'W	40	22 28 35	6/76- 9/76 12/76-4/77 7/77-11/77	Pietrafesa/DoE	C	L. Pietrafesa, N.C. State Univ.
P4	33°47'N 76°55'W	40	22 28 35	7/76- 9/76	Pietrafesa/DoE	D	L. Pietrafesa, N.C. State Univ.
P5	33°41'N 77°03'W	40	22 28 35	6/76- 9/76 12/76-4/77 7/77-11/77	Pietrafesa/DoE	E	L. Pietrafesa, N.C. State Univ.
P6	33°35'N 76°56'W	70	22 65	7/76- 9/76	Pietrafesa/DoE	F	L. Pietrafesa, N.C. State Univ.
P7	33°04'N 77°58'W	45	17 42	12/76-4/77	Pietrafesa/DoE	I	L. Pietrafesa, N.C. State Univ.
P8	33°58'N 76°25'W	75	8 17 42 72	7/77-11/77 4/78- 9/79	Pietrafesa/DoE	J	L. Pietrafesa, N.C. State Univ.
P9	34°34'N 75°56'W	45	17 42	7/77-11/77	Pietrafesa/DoE	K	L. Pietrafesa, N.C. State Univ.
P10	33°48'N 77°12'W	35	17 32	12/77-9/79	Pietrafesa/DoE	O	L. Pietrafesa, N.C. State Univ.
P11	34°12'N 76°43'W	35	17 32	12/77-9/79	Pietrafesa/DoE	P	L. Pietrafesa, N.C. State Univ.
C'	35°54'N 75°34'W	10	4 9	8/4/77- 8/5/77 10/28/77- 11/4/77	Curtin/CPRC	C'	T. Curtin (1979)
F'	35°10'N 75°47'W	10	4 9	8/4/77- 8/5/77 11/9/77- 11/19/77	Curtin/CPRC	F'	T. Curtin (1979)
I'	34°40'N 76°50'W	10	4 9	8/4/77- 8/5/77 10/28/77- 11/21/77	Curtin/CPRC	I'	T. Curtin (1979)

Table 6-4 (Continued)

Mooring	Approximate Location	Water Depth (m)	Meter Depth (m)	Date	Investigator/ Funding	Investigator's Identification	Reference or Source
L'	34°04'N 77°51'W	10	4 9	8/5/77- 8/6/77	Curtin/CPRC	L'	T. Curtin (1979)
S1	(32°32'N) 32°34'N (78°36'W) 78°37'W	(75) 46	(17) 11 (45) 23 (72) 43	11/4/77- 11/4/79 2/26/80- 6/19/80	SAI/BLM	85,89,91,92 96,97,100 (119)	SAI/NODC
S2	32°41'N 78°45'W	38	10 19 35	11/15/78- 3/20/79 5/27/79- 10/30/79 2/26/80- 6/19/80	SAI/BLM	95,99,118	SAI/NODC
S3	32°48'N 78°54'W	30	9 or 17 27	5/27/79- 10/5/79 2/26/80- 6/19/80	SAI/BLM	98,117	SAI/NODC
W1	36°00'N 74°00'W	3070	1955	5/8/79- 11/4/79	Watts	1	R. Watts, URI
W2	36°00'N 73°10'W	3685	2675 3170	5/7/79- 8/8/79 11/14/79- 7/8/80	Watts	2	R. Watts, URI
W3	36°30'N 73°40'W	3070	2060	11/14/79- 7/8/80	Watts	3	R. Watts, URI
A	33°28'N 76°53'W	198	98 178	1/16/79- 5/15/79 8/3/79- 11/18/79	Brooks-Bane/ NSF, ONR	A	D. Brooks, Texas A&M
B	33°22'N 76°41'W	390	250 370	1/16/79- 5/15/79 8/3/79- 11/18/79	Brooks-Bane/ NSF, ONR	B	D. Brooks, Texas A&M
C	33°51'N 76°15'W	385	245 305 365	1/16/79- 5/15/79 8/3/79- 11/18/79	Brooks-Bane/ NSF, ONR	C	D. Brooks, Texas A&M
D	33°55'N 76°12'W	376	236 296 356	1/16/79- 5/15/79 8/3/79 11/17/79	Brooks-Bane/ NSF, ONR	D	D. Brooks, Texas A&M
G1	36°00'N 74°55'W	77	43 49	5/11/81- 11/11/81	General Oceanics/ BLM	G1	General Oceanics, Inc./SAI/NODC
G2	36°00'N 74°35'W	1600	1489 1495	5/11/81- 11/12/81	General Oceanics/ BLM	G2	General Oceanics, Inc./SAI/NODC
G3	36°00'N 73°45'W	3090	2979	5/10/81- 2/5/82	General Oceanics/ BLM	G3	General Oceanics, Inc./SAI/NODC
G4	36°00'N 73°00'W	3560	3455	5/10/81 2/5/82	General Oceanics/ BLM	G4	General Oceanics, Inc./SAI/NODC

Abbreviations:
- BLM: Bureau of Land Management
- CPRC: Coastal Plains Regional Commission
- DOE: Department of Energy
- NODC: National Oceanographic Data Center
- NSF: National Science Foundation
- ONR: Office of Naval Research
- SAI: Science Applications, Inc.
- URI: University of Rhode Island

by Dr. T. Curtin (N.C. State University) for BLM (now MMS). The results of this analysis will be published as part of MMS's South Atlantic OCS Physical Oceanography study being coordinated by Science Applications, Inc., and due completion in 1983. In addition, earlier papers from parts of this large data base are presented by Bartlett (1883), Iselin and Fuglister (1948), and Fuglister (1951). Bumpus (1973) has reported surface and bottom drifter results on the shelf for this region.

6.2.3 Waves

Waves entering the coastal zone shoal and break, transporting water and momentum that is dissipated in coastal currents and sediment transport. Littoral currents may be caused by the waves breaking at an angle to the shoreline. The magnitude of the current depends upon the breaking angle (which itself may depend upon local topography) and the height of the wave. Studies of wave climatology which can be applied to the local area of interest are important in determining the direction and magnitude of this component. The general climatology of waves off the N.C. coast is available as a Summary of Synoptic Meteorological Observations (SSMO) collected by ships in various sectors of the Atlantic and compiled by the National Climatic Center in Asheville, N.C. Though many joint occurrences of wind and sea (height and period) are provided, the SSMO data do not provide wave direction necessary for calculation of currents and sediment transport. The SSMO data are also "fair weather biased" since most of the observations are reported by merchant ships which try to avoid storms and high waves in the interest of safety and speed.

The Coastal Engineering Research Center (CERC) of the U.S. Army Corps of Engineers has established a series of coastal wave gauges for the purpose of gathering long term wave statistics. Three of these are along the N.C. coast (Figure 6-10), and a fourth is presently in operation at Duck, N.C., at the CERC Field Research Facility north of Nags Head. The distributions of significant wave heights and periods averaged by month for all observations have been tabulated by Thompson (1977). Like the SSMO data, unfortunately, these also lack directional information and are not useful for sediment transport calculations. Visual wave observations have been taken at several coastal localities as part of the Beach Evaluation Program sponsored by CERC. The Littoral Environment Observations (LEO) format provides wave breaker angle and height estimates at coastal locations selected for special studies. Holden and Wrightsville Beaches were two such localities where LEO observations were made over periods of several years. Though these provide useful information, the observation locations are geographically dispersed and the coverage in time is spotty.

More recent wave climate studies for the East Coast have been conducted by the Corps of Engineers Waterways Experiment Station and are due for publication in the near future. This method, based on wave hindcasts techniques from 20 years of wind climate data, is designed to give wave statistics at various coastal segments. Waves generated by local winds are progressed and refracted to a given nearshore water depth.

Other wave observation methods have been applied to the N.C. coastal zone with lesser degrees of success than those mentioned above (U.S. Army Corps of Engineers, 1973), and various models may be used to determine coastal currents

Figure 6-10. Beach Evaluation Program (CERC) wave gauge locations in the eastern United States.

based on waves, winds, tides, and other forcing mechanisms. However, there are presently no systematic data collection programs aimed at determining the direction and magnitude of coastal currents.

Some effort was made by Langfelder et al. (1968) to predict littoral drift along the North Carolina coast. They also pointed out the rather limited availability of data and noted that their conclusions were "assumed to be representative of average conditions prevailing under more or less normal circumstances." Their results are presented in Figures 6-11 through 6-13. They found generally that the drift of material in the vicinity of Cape Hatteras, Cape Lookout, and Cape Fear was in the direction of the capes, and that with the exception of the probable effects of major storm events, the predicted littoral drift corroborated the observed aerial photographic trends of erosion and accretion which they had seen.

In addition to littoral drift, storm surges should also be addressed in pipeline planning. Knowles et al. (1973) broke down the North Carolina coast into five regions of wave climate. Surge data for these regions are presented in Figure 6-14 and Table 6-5. These data clearly show that the most severe wave climates are experienced along North Carolina's southern exposure between Cape Fear and South Carolina, with a decreasing trend in wave climate severity to the north. The most favorable wave climate appears as the region between Cape Hatteras and Cape Lookout.

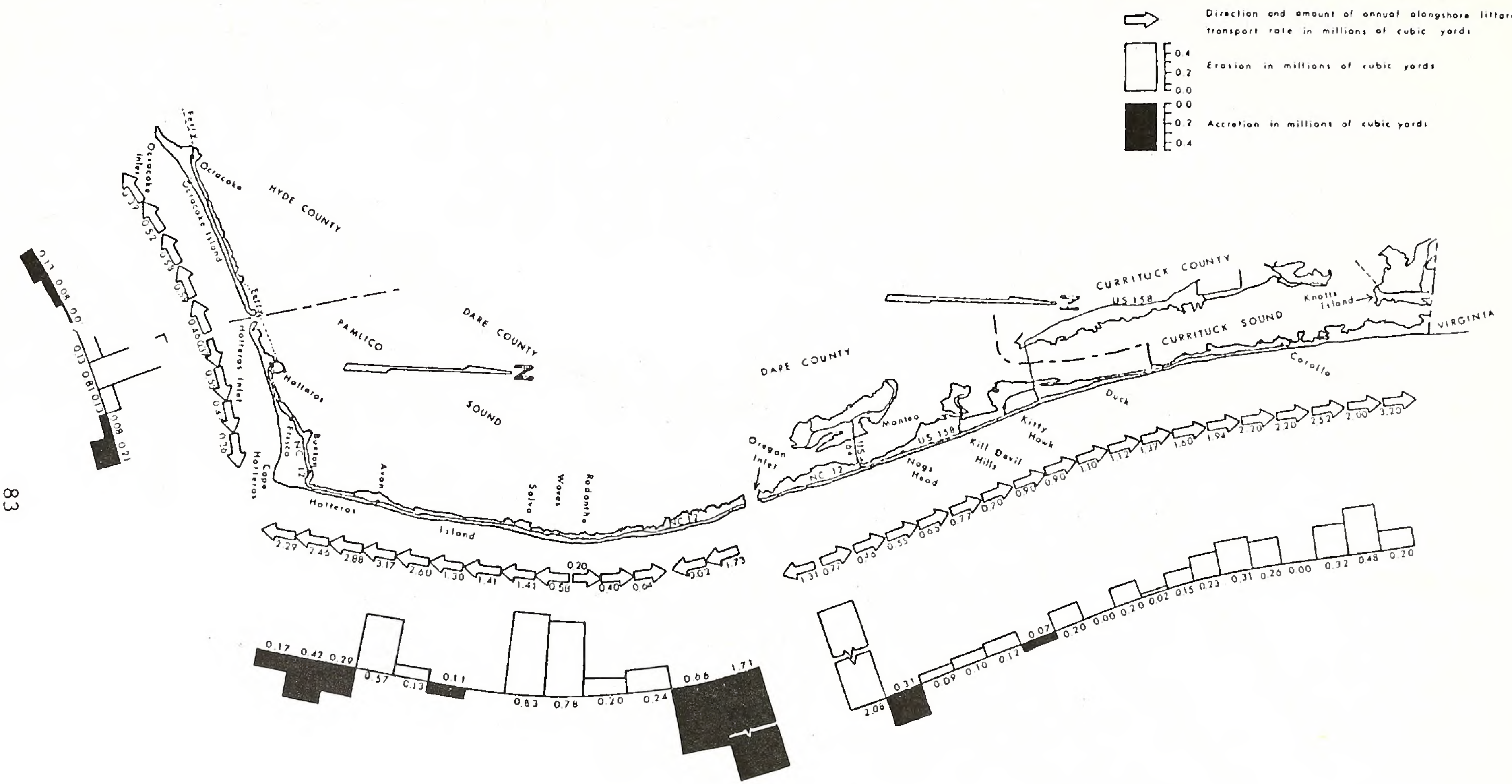


Figure 6-11. Direction and quantity of littoral transport and volumetric changes in the North Carolina coast between the Virginia line and Ocracoke Inlet. (from Langfelder et al., 1968)

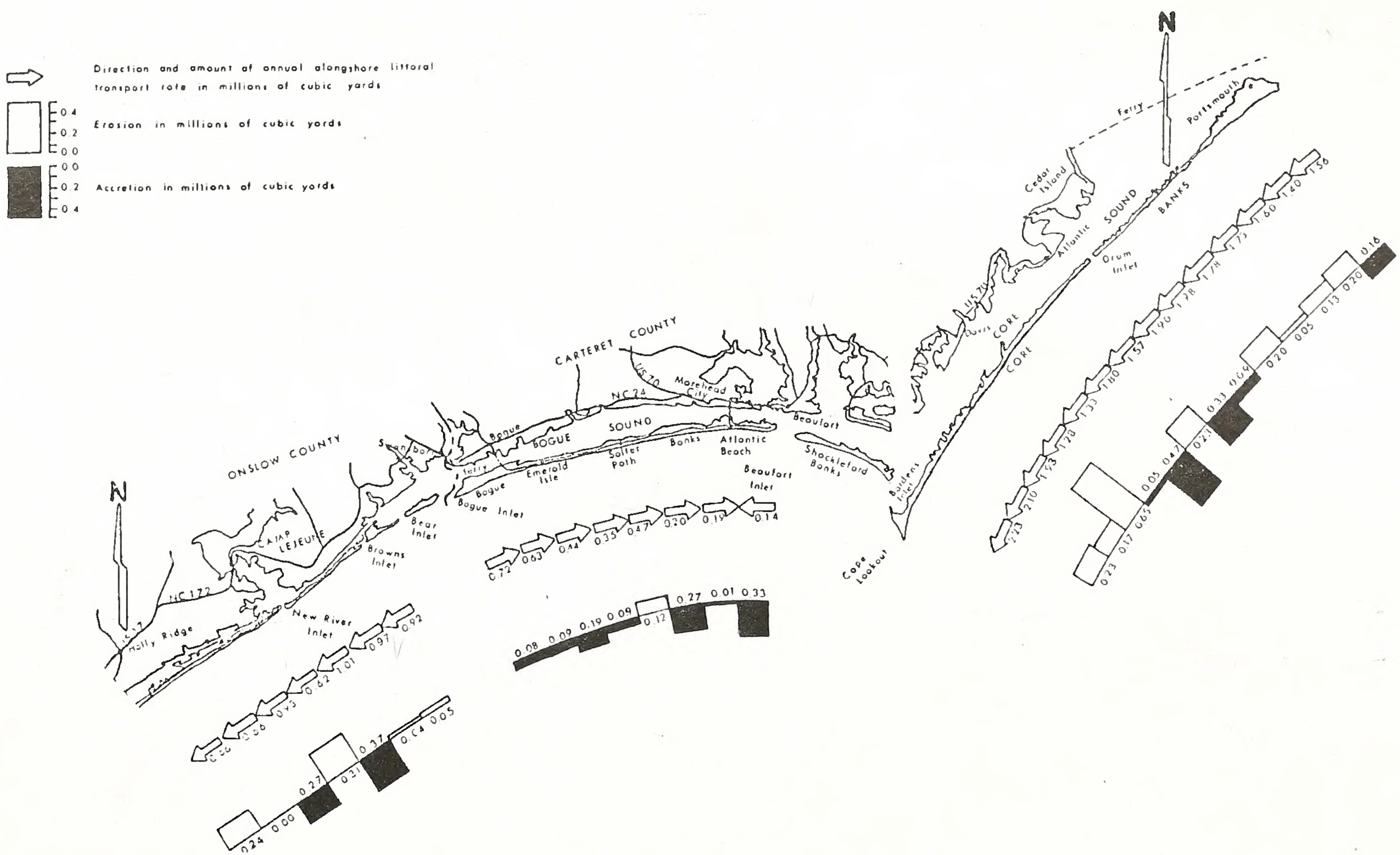


Figure 6-12. Direction and quantity of littoral transport and volumetric changes in the North Carolina coast between Ocracoke Inlet and the Onslow/Pender Co. line. (from Langfelder et al., 1968)

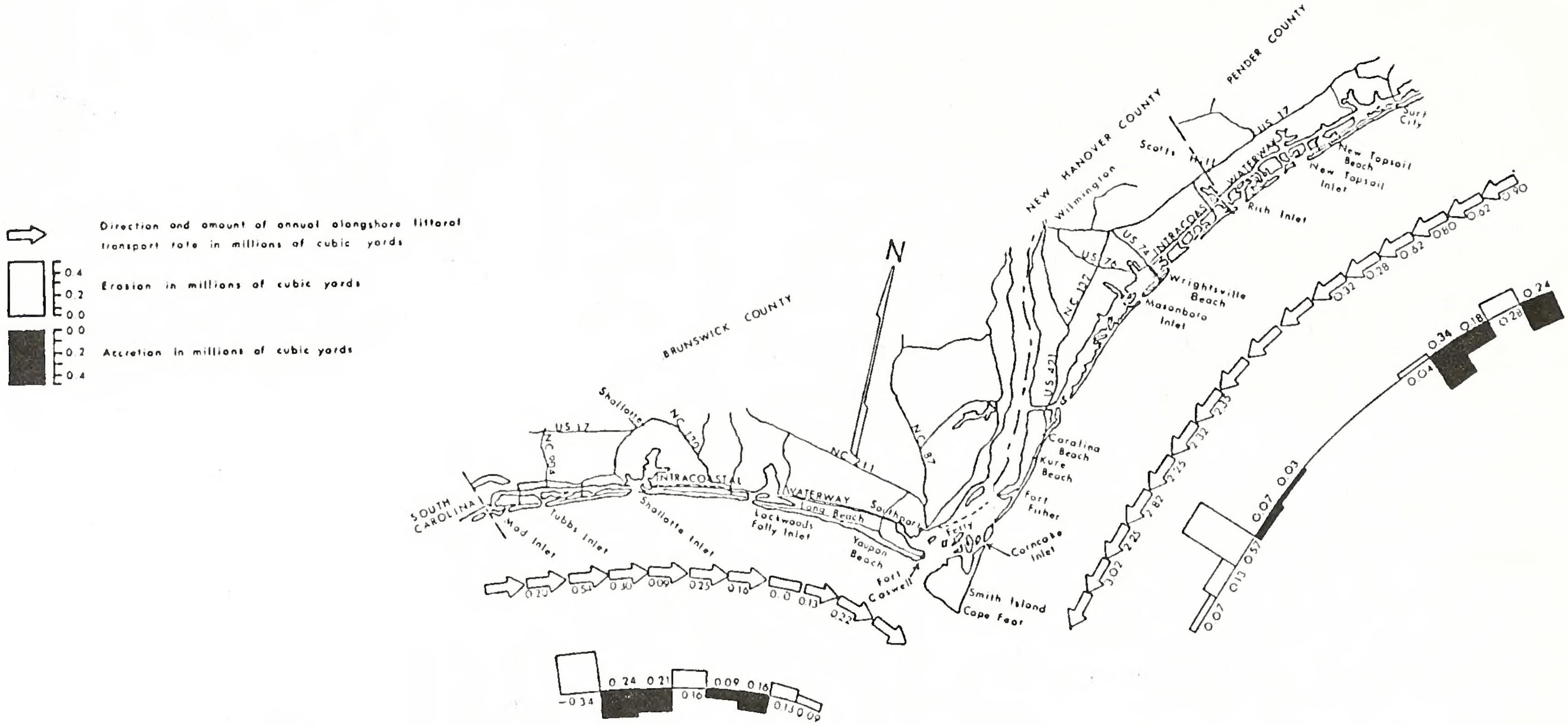


Figure 6-13. Direction and quantity of littoral transport and volumetric changes in the North Carolina coast between the Onslow/Pender Co. line and South Carolina. (from Langfelder et al., 1968)

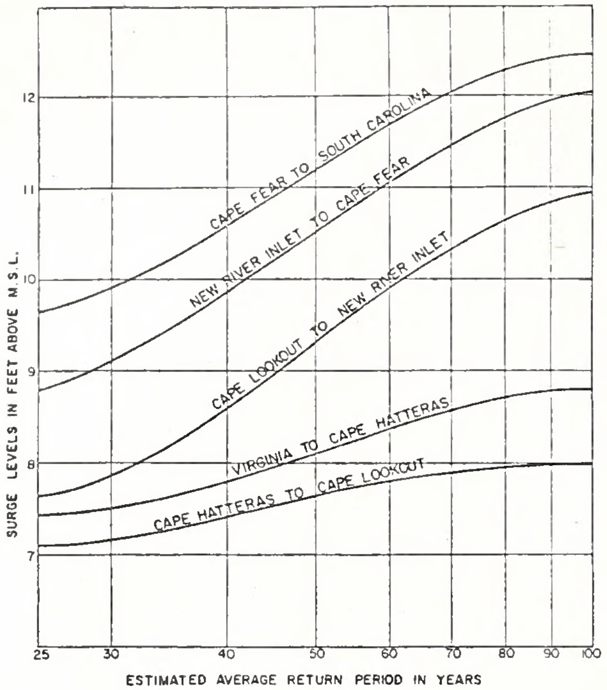


Figure 6-14. Storm surge levels related to return frequencies for five subdivisions of the North Carolina coast. (from Knowles et al., 1973)

	SURGE LEVEL(S) (+Ft.MSL)			BREAKING DEPTH(H_m) (-Ft. MSL)		
	1/25	1/50	1/100	1/25	1/50	1/100
Virginia To Cape Hatteras	7.43	8.20	8.80	7.06	7.79	8.36
Cape Hatteras To Cape Lookout	7.10	7.63	8.00	6.75	7.25	7.60
Cape Lookout To New River Inlet	7.63	9.33	10.95	7.25	8.86	10.40
New River Inlet To Cape Fear	8.80	10.55	12.05	8.36	10.02	11.45
Cape Fear To South Carolina	9.67	11.23	12.45	9.19	10.67	11.83

Table 6-5. Storm stillwater surge levels and breaking depth of waves for a one in twenty-five, fifty, and one hundred years storm return frequency, respectively. (from Knowles et al., 1973)

VII. ENVIRONMENTAL RESOURCES

7.1 ESTUARIES, BAYS, AND SOUNDS

Behind the barrier islands of North Carolina lie more than two million acres of open water and coastal marshlands, comprising the most extensive estuarine system on the East Coast. This system can be divided into four general estuarine areas (Street, 1979):

1) From the South Carolina border to White Oak River are a series of narrow estuaries characterized by smooth cordgrass (*Spartina alterniflora*) marsh, muddy bottoms, diurnal tides of 3-5 feet, and salinities of more than 20 ppt except in the rivers.

2) Between White Oak River and northern Core Sound are two large bodies of water, Bogue and Core Sounds. Diurnal tides here are generally less than 3 feet, salinities usually exceed 25 ppt, and sandy bottoms predominate, often covered with eel and shoal grass (*Zostera marina* and *Halodule wrightii*).

3) Pamlico Sound, its tributaries (particularly the Neuse and Pamlico Rivers), and bordering black needlerush (*Juncus roemerianus*) marshes cover over one million acres. The bottom type varies from muddy to sandy, salinities vary from near 0 ppt in the upper tributaries to about 25 ppt near the few inlets, and lunar tides are negligible, though irregular wind-driven tides in excess of 2 feet are not uncommon.

4) Albemarle and Currituck Sounds comprise almost 600,000 acres of open water, freshwater marsh, and wooded swamps. Wind tides are far more important than lunar tides and salinities rarely exceed 5 ppt. The bottom is mostly sandy, with extensive areas of submerged aquatics, particularly Eurasian watermilfoil, in the eastern part of the area. The only exchange with the ocean occurs through northern Pamlico Sound and Oregon Inlet.

General reviews of the brackish (0-8 ppt) portions of these systems have been written by Copeland et al. (1974a) and Copeland (1976), and of the mid-salinity (5-18 ppt) portions by Bellis (1974) and Laney (1976). The continental shelf environmental summaries (Saila, 1973; VIMS, 1974; Center for Natural Areas, 1977, 1979) review many of the studies conducted in these areas. Among the best studied areas are the Pamlico River Estuary (Hobbie, 1970, 1971; Tenore, 1970; Davis and Brinson, 1976), the system of small estuaries in the Beaufort-Morehead City area (Williams et al., 1968; Thayer, 1971; Thayer et al., 1974), and the Cape Fear River Estuary (Carpenter, 1971; Birkhead et al., 1979).

In addition to the large areas of unvegetated, subtidal bottom which comprise the majority of the state's estuarine environment, there are several habitats of more limited extent that appear to be particularly important in maintaining the productivity of the estuarine system. These areas include primary nursery areas, coastal wetlands, seagrass beds, and oyster reefs, and they will be a prime focus for concern regarding the impacts of pipelaying in estuaries. Coastal wetlands are treated in Subchapter 7.2 and are not discussed further here.

The term "primary nursery area" has been used to describe those areas where the post-larval development of a number of commercially important species, such as shrimp, spot, croaker, menhaden, and flounder, occurs in large concentrations. Though somewhat variable in character, primary nursery areas tend to be shallow areas of low salinity in the upper reaches of bays

and tributaries. They are characterized by stable, undisturbed sediments and are highly productive by definition, seasonally supporting large concentrations of young of several commercial species. Because these areas are so intensively used, they should be protected throughout the year against any major bottom disturbing activity that might reduce productivity. Most such areas below the inland/marine demarcation line have been designated by the N.C. Marine Fisheries Commission as primary nursery areas (15 N.C.A.C. 3B .1400), and the use of any trawl nets or dredges within these areas is forbidden. It has been the practice of the Office of Coastal Management to deny permits for extensive bottom disturbing activities within these areas (Pate, 1982).

Three species of seagrasses occur in North Carolina estuaries. Eelgrass (Zostera marina), common throughout the temperate zone, reaches the southern limit of its range on the U.S. Atlantic coast near Cape Fear, North Carolina. Extensive beds occur in Bogue and Pamlico Sounds. In the shallow estuaries near Beaufort, eelgrass has been estimated to cover 17% of the estuarine area and supply as much as 60% of the system's annual productivity. Shoalgrass (Halodule wrightii) is primarily a tropical and subtropical species that reaches the northern extent of its range in the vicinity of Beaufort, and widgeongrass (Ruppia maritima) is found throughout coastal North Carolina in areas of low salinity in the upper reaches of estuaries (Radford et al., 1968; Thayer et al., 1975).

The true importance of seagrass meadows to coastal marine ecosystems is not fully understood, but studies have demonstrated a number of important functions seagrasses have in estuarine systems. These include: a high rate of productivity, most of which enters detritus-based estuarine food chains; support for a large number of epiphytic organisms; provision of cover for a variety of invertebrates and fishes, particularly juveniles; the binding action of roots on sediments, thereby reducing erosion and encouraging a stable sediment-water interface; increased sedimentation around the plants as the leaves retard currents; and the transfer of phosphorus and nitrogen from sediments to the water column by the growth and decay of seagrass leaves (Thayer et al., 1975; Adams, 1976).

The eastern oyster, Crassostrea virginica, is one of the dominant estuarine organsims of the Atlantic and Gulf coasts. In North Carolina it occurs in the estuaries from Pamlico Sound south, in both subtidal and interdital locations, and forms the basis of an important commercial fishery. Oysters are typically reef building organsims that grow on their own shell substrate. A number of other sedentary organsims requiring hard substrate also attach to the oysters (including many forms of algae, hydroids, bryozoans, barnacles, mussels, and tube-building worms), and other organisms seek refuge or prey within the reefs, so that in time a diverse and distinct ecological community is established (Chestnut, 1974). Bahr and Lanier (1981) recently reviewed the ecology of intertidal oyster reefs of South Carolina and Georgia, and much of their review is applicable to southern North Carolina as well.

Other estuarine habitats include large expanses of subtidal and intertidal unvegetated flats. These have been reviewed recently by Gray (1974) and Peterson and Peterson (1979). Of direct commercial importance in these areas are shellfish beds, concentrations of shellfish on preferred

substrate that form under the proper environmental conditions (Merrill and Ropes, 1977). These beds may consist of oysters, bay scallops (generally found in seagrass stands), and hard clams.

The methods of pipelaying in estuaries were discussed in Chapter III. Methods used will vary with the length of the crossing, the depth of the estuary, the nature of the landfalls, and other factors; at least in the larger estuaries, the combined use of a flotation canal with either a push or pull landfall seems likely. Required permits for this construction were reviewed earlier in Chapter IV. These include Section 10 and 404 permits from the Corps of Engineers, and dredge and fill and CAMA major development permits from the state's Office of Coastal Management.

7.1.1 Estuarine Impacts

The major impacts of pipelaying in estuaries result from the dredging activities associated with laying and burial of pipelines. These include:

- the alteration or destruction of habitat where the trench or flotation canal is dredged and where the spoil is placed;
- increases in suspended sediment and their various effects on the water column;
- sedimentation; and
- changes in estuarine circulation.

In addition, open pipeline trenches leading from upland and marsh environments to an estuary may act as drains, increasing freshwater inflow and sediment input to the estuary.

In general, our understanding of the impacts of dredging on estuarine systems is far from complete. The interactions between sediment charactersitics, biota, circulation patterns, and the manner of disturbance are very complex, and predictions of specific impacts are not yet possible with any assurance. The effects of dredging have been reviewed recently by Morton (1977) and Allen and Hardy (1980) and have been the subject of numerous studies, particularly those of the Dredged Material Research Program (DMRP) of the Corps of Engineers. A brief summary of some of the significant findings of these studies is presented below.

Water Column Impacts. The suspension of large quantities of sediment during dredging and disposal operations will have several effects on environmental conditions within the water column. These may include a decrease in light penetration, resulting in a reduction in photosynthesis by both phytoplankton and submerged macrophytes; destruction of plankton and nekton through physical contact with the dredged material; release of nutrients and contaminants; interference with animal migrations; and depletion of dissolved oxygen levels. The magnitude of these impacts will depend on the characteristics of the site and on the dredging methods employed.

In general, dredging operations cause substantial localized increases in turbidity, but these are short-term in nature. Barnard (1978) reported that maximum concentrations of suspended solids within 500 meters of a clamshell operation will probably be less than 500 ppm, with average concentrations of roughly 100. In a study of four disposal sites, Wright (1978) found that turbidity levels rose to a maximum of 500-800 ppm during disposal, but settling and dispersal occurred rapidly, and the increased turbidity did not

persist for more than several hours. Moreover, estuarine waters tend to be turbid, and these levels are comparable to those reported from other causes. Wright (1978) noted that at most of the sites he studied, storms, river discharge and other natural phenomena resulted in turbidity increases of much greater magnitude than did disposal operations. Turbidities behind shrimp trawlers in Corpus Christi Bay were measured by Barnard (1978) at 100-550 ppm, and Mackin (1961) found that turbidities 300 feet from the discharge pipe of an hydraulic dredge in a turbid Louisiana bay did not exceed those observed during periods of rough water.

The potential for direct destruction of plankton and nekton by dredging operations is usually of little consequence, as plankton reproduce quickly and nekton avoid the area (Allen and Hardy, 1980). While some phytoplankton are destroyed during dredging operations, attempts to measure primary production have produced ambivalent results (Morton, 1977). Several researchers have theorized that the reduction in light penetration may be offset by the stimulating effect of nutrients released from the sediment.

In general, animals of turbid environments and mud bottoms are more tolerant of high turbidities than those of clear and sandy environments. Fish are known to avoid high turbidities where possible (Conner et al., 1976). Saila (1980) observes that adult fishes, crustaceans and mollusks seem to survive significant increases in turbidity over short periods. Though lab studies have catalogued a number of problems that fish may experience in turbid water (e.g., coating of the respiratory epithelium and trapping of large particles by gill lamellae, causing asphyxiation; abrasion of gills, leading to chronic bacterial infection; alteration of normal behavior and disorientation), Morton (1977) reports several studies that found no fish mortality near actual dredging and disposal sites. In one case of hydraulic dredging of the Atlantic Intracoastal Waterway, fish avoided the immediate vicinity of the dredge but did not evacuate the dredge area, perhaps so as to exploit the food organisms stirred up by dredging operations.

Larval and juvenile forms of fish and shellfish are more sensitive to high turbidities and are far less mobile than adult forms. Because of the tendency of early life history stages of some species to concentrate in large numbers in nursery areas, these species are particularly sensitive to high turbidities at these times.

High turbidities can also cause a number of physiological disorders in filter feeders, including abrasion of gill filaments, clogging of gills, impaired respiratory, feeding and excretory functions, and reduced pumping rates (Sherk, 1971, as summarized in Morton, 1977). Such disorders can reduce productivity. Because of oysters' commercial value, the responses of these organisms to high turbidities have been examined several times, with ambivalent results. Loosanoff and Tommers (1948), for instance, found that oysters can feed in turbid water, but that an increase in turbidity usually results in a decrease in feeding, and at high turbidities oysters may cease pumping altogether. On the other hand, Mackin (1961) found that concentrations of suspended sediments as high as 700 ppm had no apparent effect on oyster feeding rates and mortality. He concluded that "it was apparently impossible to maintain a suspension of high concentration long enough to cause mortality of oysters." Such apparently contradictory results

can probably be attributed to such factors as the characteristics of the sediment, time of year, indigenous habitat, and physiological condition.

Other water column impacts are primarily the result of open water disposal of dredged sediments; if spoils are disposed of within a confined area, these effects are unlikely to occur. One of these concerns is the disturbance of polluted sediments. Polluted sediments are primarily a phenomenon of heavily industrialized areas, but there are a few small locations in coastal North Carolina where toxic substances are known to occur. Several studies have indicated that, with certain exceptions, no significant release of potential toxicants (oils and greases, PCBs, heavy metals, etc.) into the water column occurs during the discharge of dredged material (Allen and Hardy, 1980). Toxic levels of some heavy metals may be released immediately after disposal, but within a few hours these levels should fall below toxic concentrations by dilution and by sorption onto iron hydrous oxide coagulates that also form during dredging (Burks and Engler, 1978). Nitrogen accumulates in sediments in the reduced, toxic form ammonia, which is highly water soluble and readily released to the water column during dredging operations. In organic sediments, hydrogen sulfide, which is highly toxic to aquatic organisms even with substantial dilution, may also accumulate (Allen and Hardy, 1980). Both of these chemical species should be monitored before and during operations.

There is often a significant release of nutrients and biostimulants during disposal operations, particularly of ammonia (which is oxidized to nitrates over several days), but also lesser amounts of ortho-phosphates (Allen and Hardy, 1980). In nutrient deficient waters such releases may have a beneficial impact, but in other cases, such as poorly mixed estuarine waters where nitrogen is often limiting, the potential exists for algal blooms and other detrimental conditions to develop.

Temporary drops in dissolved oxygen (DO) are often, but not always, observed during dredging operations (Morton, 1977). Several factors may influence dredging's effect on local DO concentrations, including the stimulation or inhibition of primary production, the biological and chemical oxygen demands of the sediment, the handling of the sediment during dredging and disposal, and the degree of flushing at the disposal site. Short-term DO depletion due to dredging is seldom a problem. Long-term anoxia can occur where highly organic sediments are released, particularly in poorly mixed waters.

<u>Bottom Impacts</u>. There are three main impacts of dredging on benthos: the destruction of organisms and habitat in the dredged channel, the burial of organisms under deposited spoil, and sedimentation from the settling of suspended particles and the redistribution of spoil piles by currents.

During dredging, most benthic organisms are removed from the site. Recolonization of the new channel is often rapid, and original biomass may be reached in two weeks to four months. However recolonization is usually by opportunistic species, and original species diversity is seldom achieved (Allen and Hardy, 1980). Recolonization studies show a high variability in recovery time and the nature of the recolonization process (Saila, 1980). Such factors as the biology of the plants and animals involved, substrate characteristics, and other environmental conditions appear to influence

recovery time. Taylor and Saloman (1968), for instance, found that recolonization of canals in Boca Ciega Bay, Florida, was negligible ten years after dredging; they attributed this to a marked change in surface sediment texture and persistent low levels of dissolved oxygen.

The fate of material disposed of in aquatic environments will depend on the disposal methods used. Much of the material discharged by pipeline dredges may leave the area as fluid mud, while material from hopper dredges, buckets and clamshells is less likely to be widely dispersed. Fluid mud can greatly stress the bottom environment, as it is usually low in dissolved oxygen and will not physically support the upward movement of buried organisms. It can be particularly deleterious where it forms a blanket over fish spawning grounds and bottom areas critical to juvenile stages of aquatic organisms (Hirsch et al., 1978).

Lab studies and limited field experiments show large differences in the abilities of benthic organisms to escape from under a blanket of sediment. Sessile or attached organisms, such as oysters, mussels and barnacles, are killed. Epifaunal forms also generally perish, while infauna show an ability to migrate to varying degrees. In one lab study, a majority of the animals observed were able to migrate up through 32 cm of dredged material. Few field studies, however, have shown any contribution of vertical migration to benthic recovery following dredged material deposition. The ability to migrate appears to depend on several factors, including the size and physiological state of the organism, environmental conditions, and particularly the degree of textural similarity between the original substrate and deposited overburden (Hirsch et al., 1978).

Recolonization of disposal areas, like dredged channels, tends to be highly variable, though certain patterns are discernible (Rhoads et al., 1978). Though succession may eventually produce a new stable community, the new habitat may be substantially unlike the one present before disposal, as a result of changes in the physical or chemical character of the bottom sediments, the loss of vegetative cover, the filling in of spawning grounds or other effects.

In general, the more naturally variable the environment, the better the biota is adapted to unstable conditions and the less impact dredging and spoil disposal will have (Hirsch et al., 1978). Like most estuaries, the North Carolina estuaries and nearshore shallows are highly variable environments, with often rapidly fluctuating turbidities, salinites, and water temperatures, and frequently shifting bottom sediments. Under these conditions, recolonization following artificial disturbance should be fairly rapid. Copeland et al. (1974b), for instance, found no pronounced effects on the benthos as a result of dredging of the intake canal of CP&L's Brunswick Nuclear Power Station through Snow's Marsh, or as a result of construction and placement of the discharge pipes off Caswell Beach. Peterson and Peterson (1979) suggest that the benthic communities of temperate estuaries in general, and of intertidal flats in particular, are highly resilient systems that should recover rapidly from disturbance.

Sedimentation from the settling of suspended particles or the redistribution of spoil piles by currents may also have adverse effects, particularly when sedimentation occurs in areas of sensitive organsisms such

as coral reefs, seagrass beds, oyster reefs and fish spawning and nursery areas. Odum (1963) examined the impacts of dredging on Thalassia and Diplanthera (Halodule) beds in Redfish Bay, Texas. Productivity and chlorophyll a concentrations dropped during the period of dredging, presumably as a result of shading by suspended sediments. Beds one-quarter mile from the dredged channel were smothered under 30 cm of soft silt, and no growth occurred the following year, while beds one-half mile away grew at substantially higher rates than before the dredging. Odum suggested that nutrients added by the settling sediments might be the cause. Studies in Long Island Sound found that areas which had been used for spoil deposition lacked vegetation, especially eelgrass, although it was abundant at nearby sites where the bottom was undisturbed (Rhoads et al., 1978).

Conner et al. (1976) report the results of several studies which demonstrate that oysters only partially submerged by mud are apparently little affected by it, while oysters completely covered with mud smother. Rose (1973) found that the mortality of market-sized oysters covered with a blanket of resuspended sediment 2-15 cm thick averaged 57% within 595 meters of a spoil bank, as compared with 17% for areas further away. Even a thin silt layer 1-2 mm thick covering hard substrates is enough to render the surface unsuitable for the setting and development of oyster larvae (Fiore, 1976).

Changes in Circulaton. An unbackfilled flotation canal and accompanying spoil banks in estuarine areas have the potential to alter circulation patterns, salinities, sediment input and deposition, and water exchange rates, with various physical, chemical, and biological ramifications (Allen and Hardy, 1980). Deep channels increase the volume of water that may go anoxic during periods of summer stratification, thus intensifying low dissolved oxygen levels in the estuary during turnover (Tenore, 1970). Changes in circulation patterns may have a significant effect on zooplankters, which include the larval and juvenile forms of many commercially valuable shellfish and finfish (Morton, 1977). Though these species have some mobility in their early life history stages, they rely heavily on currents for their migration from offshore spawning grounds to estuarine nursery areas. A classic example of the effects that spoil piles may have on estuaries is that of South Bay, near Brownsville, Texas. Dredged material from the Brownsville ship channel was placed along the north end of South Bay, closing it off except for a narrow, shallow inlet. As a result, Boca Chica Pass, South Bay's other inlet, filled in, circulation in South Bay became virtually nonexistent, the average depth decreased from 1.2 to 0.4 meters, the oyster population was destroyed, and fish and other invertebrate populations declined (Breuer, 1962).

Freshwater Inflow Into Estuaries. Pipeline canals through adjacent marshes and uplands may act as drains for freshwater runoff. The subject of freshwater drainage into estuaries has recently become a controversial issue in eastern North Carolina. Concern has been expressed that the drainage of upland and wetland systems for agriculture, peat extraction and other uses results in greater pulses of freshwater input into estuaries than occurs under natural conditions. These pulses in turn cause fluctuations in salinities that stress populations of juvenile shrimp and other species inhabiting the nursery areas receiving these discharges.

Two recent studies have examined this problem. Kirby-Smith and Barber (1979) investigated the effects of drainage and conversion of pocosin wetland

to agriculture in Carteret County over a four-year period. The major changes they found in the receiving waters were: 1) a decrease in surface water salinity; 2) an increase in turbidity; and 3) an increase in the concentration of phosphate, nitrate and ammonia, all of which were directly correlated with runoff volumes from the surrounding watershed. No significant changes were noted in bottom water salinity, oxygen concentrations, or phytoplankton biomass. More recently, Pate and Jones (1981) examined four primary nursery areas in northern Pamlico Sound, two of which received runoff from artificial drainage ditches. Their research showed that salinities at the two unaltered sites were more stable during periods of high runoff than those recorded at the two sites receiving ditch drainage. Furthermore, the most significant reduction in production of juvenile brown shrimp occurred at the extensively ditched site during periods of moderate to heavy rainfall, and productivity of five additional species of fish and shellfish was significantly higher at the unaltered sites.

The intersection of an upland ditch or marsh canal with the estuary can also serve as the point of entry for large quantities of sediment into the estuary. Unless these intersections are blocked during construction, highly turbid ditch water will drain into the adjacent estuary, creating a turbidity plume (Gowen and Goetz, 1981).

7.1.2 Mitigation

Measures are available for reducing the severity of most of the pipelaying impacts considered above.

Huston and Huston (1976) and Barnard (1978) discuss ways of reducing turbidity caused by dredging operations. Many of these techniques simply involve good dredging procedures and proper use of existing dredging equipment; the authors also recommend improved supervision and inspection procedures, training of dredge personnel, requirements for scheduling and operations that are incorporated into dredging contracts, preferred pipeline discharge configurations, and such technical innovations as watertight buckets.

Under certain conditions, silt curtains can be effective in reducing the spread of turbid waters. Given relatively quiescent current conditions (5 cm/s or less), turbidity levels in the water column outside the curtain can be as much as 80-90% lower than levels within the curtain. Curtains do not contain turbid water indefinitely, but divert its flow under the curtain, thereby minimizing turbidity in the upper water column outside. To some extent, they also encourage more rapid settling of suspended sediments. Curtains are effective only in relatively quiet waters and are not recommended for use where currents exceed 50 cm/s (1 knot) or in the open ocean (Barnard, 1978). Curtains have been used in North Carolina, primarily in the vicinity of oyster beds and primary nursery areas, and they have been required in connection with pipelaying operations near oyster beds along the Louisiana coast (Dunham, 1981; Pate, 1982).

Sediments can be tested for their toxic substances content, but no simple tests to predict uptake by organisms are available (Hirsch et al., 1978). If contaminated sediments along a proposed route are found, two available alternatives are: 1) rerouting; and 2) the use of dredging methods causing

minimal disturbance combined with complete confinement of the spoil. One or the other of these alternatives is commonly required by the Corps and the Office of Coastal Management (OCM) in North Carolina where tests show the presence of toxic substances in the sediments.

The removal of spoil piles and the backfilling of the pipeline ditch and flotation canal to their original elevations will eliminate the potential for changes in estuarine circulation, salinity patterns, and other parameters. Backfilling preferably should be done with the original spoil. Backfilling is almost always required during pipelaying operations in Louisiana and for similar operations in North Carolina (Burke, 1981; Wright, 1982). An occasional exception is the prohibition of backfilling in areas particularly sensitive to turbidity, as in the vicinity of oyster reefs (Pate, 1982).

If the trench and flotation canal are backfilled, the problem of spoil disposal becomes a matter of how and where to stockpile it. The available options, in order of increasing environmental impact, are on barges, at upland sites, and in marshes and open water areas. The latter two are least preferable, as not only are existing biota destroyed, but currents may also redistribute the sediment before it is removed. In North Carolina, the Corps and OCM have permitted temporary stockpiling next to the ditch for utility line trenches excavated with clamshell buckets or similar dredges that do not cause wide dispersion of sediments (Pate, 1982; Wright, 1982).

Where backfilling may not be possible or desirable, there are several options for spoil disposal. As discussed earlier, open water disposal is not desirable from an environmental standpoint for several reasons, and it is now the general policy of the Corps and OCM not to permit open water disposal. With the possible exception of deep ocean disposal, regarding whose impacts very little is known, confined upland disposal appears to have the least environmental impact of the various alternatives and is now the method of choice in North Carolina and many other parts of the country.

The creative use of dredged spoil to provide new habitat is a relatively young concept that has received a great deal of attention during the past 10-15 years. The possibilities for habitat development should be carefully examined if substantial quantities of dredge spoil must be disposed of. Smith (1978) discusses the four basic options for habitat development (upland, marsh, island, and aquatic) and presents procedures for considering, selecting, and designing habitat management alternatives. The technology of marsh development, discussed later in the section on Coastal Wetlands, is the most advanced.

The potential use of dredge spoil in North Carolina for development of island habitat for colonial waterbird nesting colonies has been examined by ornithologists James Parnell and Robert Soots. Along the North Carolina coast in 1977, 93% of the wading birds and 76% of the gulls, terns and skimmers censused nested on dredged material islands (Parnell and Soots, 1979). Soots and Parnell (1975) demonstrated that bird use of dredged material islands in North Carolina is directly related to the successional stage of island vegetation. This raises the possibilitity of using dredge spoil to manage island vegetation for nesting birds. The Corps has been reluctant to embrace such a scheme because of the constraints it would place on their use of disposal areas, but the technique is well-suited for activities like

pipelaying with a one-time generation of spoil. The various considerations in using spoil for managing colonial nesting bird habitat are discussed by Soots and Landin (1978).

Several steps can be taken to minimize impacts on, and to restore, particular aquatic habitats. Shellfish beds (both oysters and clams) within the area to be disturbed can be harvested and/or transplanted. Since this might entail moving more shellfish than would be destroyed by pipelaying operations, the State of Louisiana has sometimes required applicants to move an equivalent volume of shellfish from polluted to non-polluted waters (Dunham, 1981). Following disturbance, restoration of shellfish beds can be attempted by reseeding the area with hatchery clams or with shellfish from polluted areas, and oyster cultch can be deposited as substrate for settling larvae.

Techniques for the restoration of seagrass beds have been developed, though with varying success (see Phillips, 1980; Thorhaug, 1980). In a recent experiment in North Carolina, Zostera was successfully transplanted in Back Sound, Carteret County. Sixteen months after transplanting, Zostera density and biomass was comparable to that of undisturbed areas (Fonseca et al., 1979; Kenworthy et al., 1980), and benthic macrofaunal populations, including commercially valuable bay scallops and hard clams, had also become re-established at levels comparable to nearby undisturbed grass beds (Homziak, 1982; Homziak et al., In Press). Fonseca and Kenworthy, both with the Beaufort Laboratory of the National Marine Fisheries Service, are currently working with the Corps to develop transplanting techniques for use of Zostera and Halodule in stabilizing dredge spoil.

Drainage of fresh water and sediments into estuaries from upland and marsh pipeline ditches can be easily minimized by the proper use of plugs and dams. Their use and construction are discussed in the following section on coastal wetlands (Section 7.2).

The timing of construction can play an important role in limiting pipelaying impacts in estuaries. Of the organisms seasonally sensitive to dredging impacts, the most significant are the larvae and juveniles of commercially important shellfish and finfish. Their times of peak abundance vary. In North Carolina juvenile brown shrimp, for instance, occur in peak numbers in the spring, young spot and croaker in the early summer, and young pink shrimp in the late summer and early fall. Oysters and clams spawn from May to September.

Because of the near-continuous utilization of North Carolina estuaries as nursery grounds throughout the spring and summer, the state's Office of Coastal Management and the Corps generally prohibit estuarine dredging between April 1 and October 1 (Wright, 1982; Pate, 1982). This prohibition is extended slightly in the southern part of the state (New Hanover and Brunswick Counties), where the active growing season is longer. Dredging is also restricted at other times of the year in certain areas, such as during spawning runs (February to early May) in coastal rivers. Rhoads et al. (1978) suggest a second reason for winter dredging: the period of intensive colonization and population growth on disturbed estuarine sediments occurs during spring, summer and fall, so that rapid recovery and high productivity will be best promoted by winter operations.

Despite the various measures discussed above, route selection remains the most effective means of avoiding impacts to specific valuable habitats. Areas that should be generally avoided are:

1) primary nursery areas, because of their intensive use as nurseries by a number of commercial and recreational finfish and shellfish;
2) oyster reefs and other high-density shellfish beds, because of their commercial and recreational value;
3) beds of submerged grasses and other aquatic plants, because of their importance in providing food, cover, substrate, erosion protection, and other valuable functions to the estuarine and larger coastal systems; and
4) areas of industrially polluted sediments, so as to avoid introducing toxic materials into the water column during pipeline construction.

In addition, estuaries and sounds in general should be avoided because of their value as biologically productive areas and important nursery grounds. It will be impossible to cross the coastal zone without passing through estuarine waters, but the choice of the shortest possible distance is strongly recommended. Where flotation canals are necessary, the area of bottom disturbed will be much greater, and therefore pipeline routes should be chosen to minimize the length of flotation canal needed, as well.

Sources. Most valuable or "primary" nursery areas within the jurisdiction of the Marine Fisheries Commission have been identified and are described at 15 N.C.A.C. 3B .1400. These areas have also been entered into the Land Resources Information Service's (LRIS) computer as part of that office's Submerged Lands Project, and computer-generated maps of these areas are available. The Division of Marine Fisheries is currently attempting to establish more specific criteria for the designation of these areas to provide better justification for the protection of areas already designated, and to provide guidance to the Division of Marine Fisheries, Office of Coastal Management, Wildlife Resources Commission, and others for the management of areas not yet formally designated (Pate, 1982). As a result, the area in which the Office of Coastal Management routinely does not permit major bottom-disturbing activities may expand during the next few years.

The only comprehensive survey of submerged grass beds in North Carolina coastal waters has recently been completed by the Office of Coastal Management under a grant from the Coastal Energy Impact Program. The area covered stretches from Bogue Inlet to Ocracoke Inlet and includes all of Bogue, Back, and Core Sounds. The final report, with maps, should be available during early 1983 (Carraway, 1982). We are unaware of any other extensive mapping surveys of grass beds and other submerged aquatics in North Carolina, although the distribution of these plants is generally known and Division of Marine Fisheries and Office of Coastal Management personnel could apprise pipeline companies of their approximate location.

As part of the LRIS Submerged Lands Project, the Division of Marine Fisheries has also mapped known oyster producing areas and oyster rehabilitation sites in state waters. This data set, available from LRIS, is defined as "those areas which historically or currently produce oysters or which are potentially productive due to bottom type, salinity and management practices" (Marshall, 1982). Comparable maps of clam and scallop producing areas do not exist, though as with grassbeds, DMF personnel are able to provide general information on their distribution.

There are only a few small estuarine areas in North Carolina where the sediments are known to have a high probability of containing industrial toxins, and their locations are available from the Corps or Office of Coastal Management.

7.2 COASTAL WETLANDS

Large acreages of vegetated coastal wetlands occur in North Carolina, found for the most part in the protected areas behind the barrier islands and along the mainland shores of the sounds and larger rivers. These marshes may be divided roughly into three types (Cooper, 1974; Cooper et al., 1975):

1) Regularly flooded salt marsh. These marshes are found primarily in the narrow coastal sounds between Cape Lookout and the South Carolina border. Here, where diurnal tides average 2-5 feet, broad, almost level expanses of marsh occur between mean sea level and mean high tide, dominated by smooth cordgrass (*Spartina alterniflora*). Soils are typically soft, grey and silty. Under the tidal influence, marsh creeks develop a dendritic form, giving the marshes their characteristic dissected pattern. Near mean high tide, cordgrass may be mixed with glasswort, sea lavender, and black needlerush, the latter typically forming a narrow fringe at mean high tide. Above this point, in the area flooded only by storm tides and the higher spring tides, saltmeadow cordgrass (*Spartina patens*) is the dominant, often mixed with saltgrass and other species. Soils in this zone tend to be sandier and markedly lower in salinity.

2) Irregularly flooded salt marsh. Vast areas behind the Outer Banks, fringing Core, Pamlico and lower Currituck Sounds, are occupied by irregularly flooded salt marsh. Here lunar tides are small to nonexistent; the larger tides are wind driven, irregular in occurrence and height, and the flooding waters brackish. The soils that develop are varying mixtures of sand and peat. Two community types are common: (a) Black needlerush (*Juncus roemerianus*) occurs in vast, pure stands just above mean high water, while on slightly higher and sandier ground, one may find sea myrtle, sea ox-eye, and big cordgrass intermixing with the needlerush; (b) on still higher ground, above the effects of all but extreme storm tides, saltmeadow cordgrass occupies extensive stands, with lesser amounts of saltgrass, bulrush and camphorweed mixed in. Wet openings and brackish ponds occur frequently in this higher zone.

3) Freshwater marsh. In upper Currituck Sound, along the borders of Albemarle Sound, and in the lower reaches of the Cape Fear and other coastal plain rivers, extensive stands of freshwater marsh occur. Bulrush, cattail, sawgrass, and big cordgrass are the major species. Soils tend to be peaty and waterlogged.

The most recent survey of these wetland types covering the entire North Carolina coast is that of Wilson (1962), whose results are summarized in Table 7-1. The U.S. Fish and Wildlife Service is in the process of conducting a nationwide wetlands inventory to update their 1954 survey. Most of the aerial photography to be used for the survey has already been flown, but unfortunately funds for map production have been difficult to acquire, and the first wetlands maps for the state, covering selected portions of the coastal area, will not be available until 1983 at the earliest.

Table 7-1. Coastal Wetland Acreage in North Carolina, 1957-1959. (from Wilson, 1962)

Type	Area
Regularly flooded salt marsh	58,400 ac.
Irregularly flooded salt marsh	100,450 ac.
Fresh marsh (shallow and deep types)	47,500 ac.

Coastal wetlands are highly productive environments. Average productivity estimates assembled by Cooper (1974) for regularly and irregularly flooded salt marshes in North Carolina ranged from 640-961 g dry weight/m^2/yr, while several community types exceeded 1300 g/m^2/yr; for comparison, 1050 g/m^2/yr is the average for highly productive hay fields in the U.S. The majority of this production, at least in regularly flooded salt marshes, enters the detritus based food chain, where it supports a variety of marsh inhabitants: fiddler crabs (*Uca* spp. and *Sesarma* spp.), horse mussels (*Modiolus demissus*), salt marsh periwinkles (*Littorina irrorata*), mud crabs (*Eurytium limosum*), clapper rails, raccoons, and others. Large numbers of immature and mature fish and shellfish inhabit the tidal creeks and shallow waters associated with the marsh, including oysters, hard clams, blue crabs, larval and mature shrimp, and juvenile and mature forms of many commercially valuable finfish, including flounder, menhaden, bluefish, croaker, tarpon and others (Cooper, 1974). In all, it estimated that some 95% of the fish caught in North Carolina are dependent on salt marshes and their associated waters during some part of their life cycles. Fresh marshes and the brackish ponds of irregularly flooded marshes also serve as major waterfowl feeding and resting areas. Clark and Clark (1979) have catalogued a number of other marsh values in addition to biological productivity, including storm buffering, water quality improvement (by removing sediment and nutrients from waters flowing over the marsh), and the provision of an aesthetically pleasing landscape.

7.2.1 Impacts of Pipeline Construction

As discussed previously in Chapter III, two methods of pipeline construction traditionally have been used in wetlands. In marshes with relatively firm soils, a narrow ditch is excavated and the pipeline floated into the ditch from a stationary lay barge or ground-based site. In softer, muddier marshes, a flotation canal may be dredged, large enough to accommodate a shallow-draft lay barge, which moves through the canal laying the pipeline much as is done in a standard offshore operation.

Experience, mainly from the Gulf, indicates that pipeline construction through coastal marshes may have a number of adverse effects on these systems, and these are discussed below. The severity of these impacts will vary considerably depending on the specific site conditions, the construction methods used and the degree of restoration achieved. Most of the research on the effects of pipelining was done in Louisiana before backfilling of canals and other forms of restoration became common in the late 1970's; the

discussion below is based on that research, and assumes more or less a "worst case scenario" of canals left unplugged and open. The discussion on mitigation later in this section will cover both the measures that have become relatively standard requirements for pipeline canals in the last 5-10 years and additional steps that can be taken to further reduce environmental damage. Several good studies and reviews have been done on the effects of pipelining in marshes, the best of which is probably McGinnis et al. (1972). Other useful reports are Willingham et al. (1975), Conner et al. (1976), Darnell (1976), and Longley et al. (1981).

Alteration of Wetland Hydrology by Canals and Spoil Banks. If the pipeline canal is left open and undammed, like any other watercourse it may act as a conduit, carrying water more swiftly and efficiently through the marsh than previously. This may have several results: (a) The canal may provide a channel for tides to penetrate further into the marsh. The resulting intrusion of salt or brackish water will be most severe where the channels are deep and where canals extend up a hydrologic basin rather than across or perpendicular to water flow. The result may be an increase in average salinity for the affected portions of the marsh, or simply an increase in the salinity fluctuation experienced during the tidal cycle. (b) The canal may also act as an interceptor, diverting freshwater upland runoff directly to the estuary and depriving marsh seaward of the canal of freshwater, sediment and nutrient input (Darnell, 1976). As discussed in the previous section on estuaries, this also increases the magnitude of freshwater pulses to the estuary and increases the estuarine input of nutrients and pollutants that would otherwise be filtered out (Craig et al., 1979). (c) By intercepting and accelerating runoff, open pipeline canals may also lower the water table and so partially drain the marsh.

Canal dredge spoils may also alter marsh hydrology, particularly when deposited as long and continuous banks on one or both sides of the canal. By blocking small tidal creeks and preventing sheet flow across the marsh, such banks may alter the duration and frequency of tidal flooding. In severe instances, particularly where spoil banks intersect, the result can be a permanent impoundment or a rarely flooded area (Conner et al., 1976).

Such changes in hydrology may effect wetland biota in several ways. Marshland vegetation patterns are largely controlled by water depth and salinity and often are quite sensitive to these factors, with slight changes resulting in replacement of some species by others. Where canals allow saline waters to penetrate formerly fresh or brackish areas, changes in vegetation ranging from minor shifts in species to complete die-back of vegetation may result (McGinnis et al., 1972). Even where average salinity does not change, increased salinity fluctuations may have pronounced effects. Many animal species that inhabit marshes, such as juvenile shrimp and mature oysters, exhibit marked salinity preferences and tolerances that may be exceeded by canal-induced increases in the amplitude of salinity fluctuations.

Canals may also open up previously isolated areas for utilization as nurseries. On a grand scale, dredging of the Gulf Intracoastal Waterway opened up much of the coastal marsh between Sabine Lake and Galveston Bay, Texas, to estuarine species. It is also possible that saltwater intrusion may improve habitat utilization in areas of low salinity, but this is apt to be

accompanied by habitat deterioration elsewhere as a result of excessive salinity levels (Conner et al., 1976).

The interruption of drainage by spoil banks may retard normal flushing and the distribution of nutrients and detritus between marsh and creeks. Banks may also cause waterlogging of large areas of marsh, leading to vegetation dieback and a decline in marsh productivity. Such diebacks may result from a number of causes, including increased soil salinity, chlorosis from lack of available iron, hydrogen sulfide toxicity, and deficiency of oxygen in plant roots (McGinnis et al., 1972).

2) <u>Changes in Habitat from Marsh to Open Water and Upland Ridge</u>. Where marsh restoration is not attempted, the most direct impact of pipeline construction is the conversion of marsh habitat within the area of the canal to open water. The magnitude of this loss is directly related to the width of the canal, as illustrated in Figure 7-1. Though the loss due to one or two pipeline canals will be relatively insignificant, the cumulative effect of many canals can be substantial. Louisiana serves as a good case in point. Craig et al. (1979), in reviewing studies of land loss in coastal Louisiana, noted that estimates of cumulative land loss to canals of all types (pipeline, rig access, and navigation) in the extensive Barataria Basin ranged from 1.0-2.6% of the total marsh area, and found the upper figure to be more credible. McGinnis et al. (1972), after reviewing the available evidence, concluded that pipeline canals were responsible for the loss of 1-2 square miles of Louisiana marsh and land per year, compared with a total loss of 16.5 square miles/year from all sources.

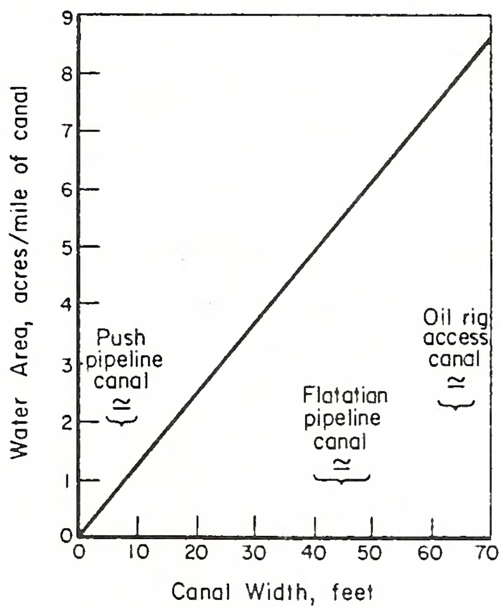


Figure 7-1. Loss of land area from canals. (from McGinnis et al., 1972)

There will also be a loss of marsh habitat to spoil banks, though the duration of the loss will depend on whether the spoil is left on the bank or backfilled into the trench. A common figure for the area covered by spoil is 2-3 times the area of the canal. When all factors are included, it is estimated that the area of marsh whose productivity is altered by pipeline construction (i.e., the canal, spoil bank, and construction area) is roughly 5-6 times the area of the canal (Craig et al., 1979).

As a result of these habitat changes, there will be at least a temporary loss of productivity within the area disturbed until new plant communities can colonize the disturbed sites. There will probably be a long-term loss as well, since it is unlikely that either the new aquatic habitat or the upland spoil bank will match the productivity of the former marsh. Individual species will fare differently, depending on their specific requirements. Marsh inhabitants and species that utilize the marsh as a nursery or are dependent upon its production will suffer the most. As this group contains a number of commercially important species, marsh habitat destruction will generally be the most serious impact of pipelining in wetlands. On the other hand, species such as reptiles and amphibians dependent on open water may benefit from canal construction. Likewise, where stable spoil areas revegetate, the new plant communities will increase habitat diversity and provide shelter, and possibly food, to upland species, including deer (McGinnis et al., 1972).

3) Suspended Sediments and Water Quality. Dredging of pipeline canals will produce temporarily high levels of turbidity within the canal and adjacent waterways, the impacts of which were discussed in the previous section on estuaries. The sedimentary particles and interstitial waters released by dredging may contain a variety of substances harmful to aquatic organisms, including hydrogen sulfide, methane, a variety of organic acids, heavy metals, and pesticides (Darnell, 1976). Nutrients may also be released in substantial quantities, causing eutrophication of stagnant canals and adjacent waterways. Moreover, marsh dredge spoils are usually anaerobic and chemically reduced, and therefore possess a large biological and chemical oxygen demand. It is to be expected that the disturbance of these sediments during dredging will temporarily lower oxygen levels in canal water.

Marshland soils usually contain high levels of sulfur, which in anaerobic environments are found in three reduced forms: hydrogen sulfide, free sulfur, and iron sulfides. The first of these, hydrogen sulfide, is highly toxic to plants. Furthermore, when marshland soils are exposed to air by lowering of the water table or construction of spoil piles, the reduced forms of sulfur begin to oxidize, producing small quantities of sulfuric acid. The combination of sulfides and acids released during pipeline construction may be sufficient to cause extensive vegetation damage, the extent of damage being related to the amount of runoff from spoil banks and the aerial extent of water table lowering (McGinnis et al., 1972).

4) Canal Erosion. The widening of canals through erosion of canal banks has been a significant problem in coastal Louisiana. The primary cause is propeller wash from boat traffic, but in some cases currents may cause significant scouring action. The problem is by no means minor: there are examples of exploration canals widening from an initial 65 feet to 140 feet in less than six years, and one small pirogue canal, 3 feet wide and 6-10 inches

deep, was observed to widen over the years to a canal 200 feet wide and 8 feet deep. Craig et al. (1979) cite studies showing annual rates of canal widening between 2-14% in coastal Louisiana.

Pipeline canals are generally not intended for navigational use, and the prevention of boat traffic is one of the principal reasons for plugging canals after construction. Plugs occasionally wash out, however. In addition, where a canal has offered an attractive shortcut to determined boaters, there are examples of dams being dug out, burned, or dynamited to permit boat entry (McGinnis et al., 1972). In such cases, frequent inspection and maintenance will be necessary.

5) Other Impacts. The compaction of soil and trampling of vegetation by surveying and construction equipment can be a significant problem. Vehicle ruts and depressions may collect standing water and in time become open water areas. Deep ruts may also alter drainage patterns. Confinement of traffic can prevent widespread damage, but restricition of traffic to one or two routes without additional support (e.g., mats) may cause excessive churning and deep ruts.

Other effects of wetland installation include deterioration of marshland's storm buffering capacity and aesthetic values.

7.2.2 Mitigation

Many of the impacts discussed above are readily preventable. A variety of measures are currently available that in most places can virtually eliminate the long-term impacts of wetland installations and significantly reduce the duration and severity of short-term effects. For purposes of discussion, these are grouped into three categories: route location, construction methods, and restoration.

Route Location. Consideration of the potential impacts discussed above suggests the following strategies for routing pipelines to minimize wetland damage:

1) Avoid wetlands altogether. This is the most obvious solution and should be done whenever possible. Unfortunately, many wetlands in North Carolina occur as long, continuous fringes along the shorelines of the barrier islands and mainland, and avoidance will often be impractical.

2) Where wetlands must be crossed, select the route that minimizes the length of crossing. In most cases this will minimize the impact as well.

3) Route the pipeline through wetland types of lesser value. Coastal marshes are not uniform in their value or in the services they provide. Some, like *Spartina alterniflora* marsh, are very important for the food and cover they provide to commercial fish populations and for their role in erosion control. Other types, like *S. patens*, are far less productive. We are unaware of any studies which specifically evaluate different wetland types with regards to which are more "expendable" than others, but many wetland studies provide evidence for such a hierarchy of values. Both the North Carolina Office of Coastal Management and the Wilmington office of the Corps use an informal hierarchy in evaluating permit applications for construction

projects in wetlands. Spartina alterniflora marsh is most highly regarded, Juncus marsh is second, and other wetland types (S. cynosuroides, S. patens, Distichlis, etc.) are ranked lower.

4) Route the pipeline through wetlands that have been damaged or degraded in some way, and so are not as valuable as adjacent pristine areas. An excellent example is the siting of pipelines adjacent to roadbeds. Developed areas where bordering marsh has already been eliminated are attractive sites if other conflicts can be avoided, and the siting of pipelines in mosquito ditches is another possibility. Where the restoration of former pipeline installations has been less than fully successful, these installation sites are also good candidates for new pipelines. It is now common practice in Louisiana to require new pipelines to be built adjacent to existing pipeline rights-of-way, thereby establishing pipeline corridors that minimize the area of marsh degraded and the continuing dissection of large marsh tracts. Natural corridors may also be available, such as creeks and channels between marsh islands. These may be a mixed blessing -- while installation through them will minimize disturbance of the marsh surface, the creekside habitat that will be disturbed is often the most productive and most important in controlling erosion.

5) Craig et al. (1979) recommend that no new canals be dredged that connect (a) the edge and center of a hydrological basin, and (b) fresh and saltwater areas. The advice is more applicable to coastal Louisiana, where vast marshland drainages sensitive to changes in salinity gradient and water flow occur, than to North Carolina. If the canals are plugged and backfilled to eliminate water flow, this caveat will be unnecessary.

Construction Methods. The choice of the particular methods and precautions employed during construction will substantially influence both the magnitude of the initial impact and the recovery time. Steps that can be taken are:

1) Minimize the area of marsh disturbed by construction activities. The most important decision in this regard is the choice between push-ditch and flotation-canal construction. Push ditches typically require less that one-fifth the area of canals. Flotation-canal installation is no longer permitted in Louisiana marshes, and there is no apparent reason why it should be permitted in North Carolina. Marshes in this state are firm enough to support construction vehicles on mats, and nowhere are they too wide to permit push-type installation.

A second way to reduce the area affected is to minimize placement of spoil on the marsh. If the ditch will not be backfilled, the spoil should not be placed on the marsh surface but taken immediately to its ultimate disposal site, which in most cases will be an upland location. If the trench will be short and backfilling is planned, the spoil should be stockpiled on a barge or upland site. The Corps has also allowed stockpiling on marsh within the area to be dredged, requiring the contractor to push ahead a growing mound of spoil. For longer ditches, such methods may not be practical, and temporary stockpiling on the marsh surface will be necessary, in which case it should be done on one side of the canal only.

A third step that can be taken is to restrict construction vehicle traffic to specific corridors and to minimize travel on the marsh. In this

regard, Longley et al. (1981) have recommended that two stipulations be attached to pipeline right-of-way grants:

> "Ingress and egress to and from the pipeline during construction shall be limited to the minimum number of vehicles necessary and to the areas of right-of-way for the pipeline, the permit area, and existing road and waterways, unless otherwise authorized by the land manager or this permit."

> "All equipment movement along the construction right-of-way shall be kept to a minimum during construction. Marsh buggies shall not make collection trips along the line to pick up personnel. On completion of a day's work, this equipment shall go directly to the canal bank and park against the toe of the levee (not on top of the levee). Boats shall collect crews along the canal banks for trips out of the marsh."

2) Schedule installation to minimize disturbance and promote restoration. Two factors favor winter installation. First, wetlands are most productive during summer and are used intensely as nursery areas by juvenile fish and shellfish from spring through fall. Second, the best success with marsh plantings has been achieved when backfilling is completed by February, allowing several weeks for the fill to settle before the optimum planting period in late March and early April.

The different phases of installation should also be carefully timed so that the ditch is open and the spoil exposed for the minimum time possible.

3) Temporary plugs should be used during construction at all waterway crossings to limit saltwater intrusion and other hydrologic changes, and to prevent the discharge of highly turbid, possibly anoxic water to natural waterways. Where the waterway is narrow, the plug should block the waterway itself; at wider waterway crossings and at the estuarine end of the marsh, the temporary plugs should block the canal (Figure 7-2).

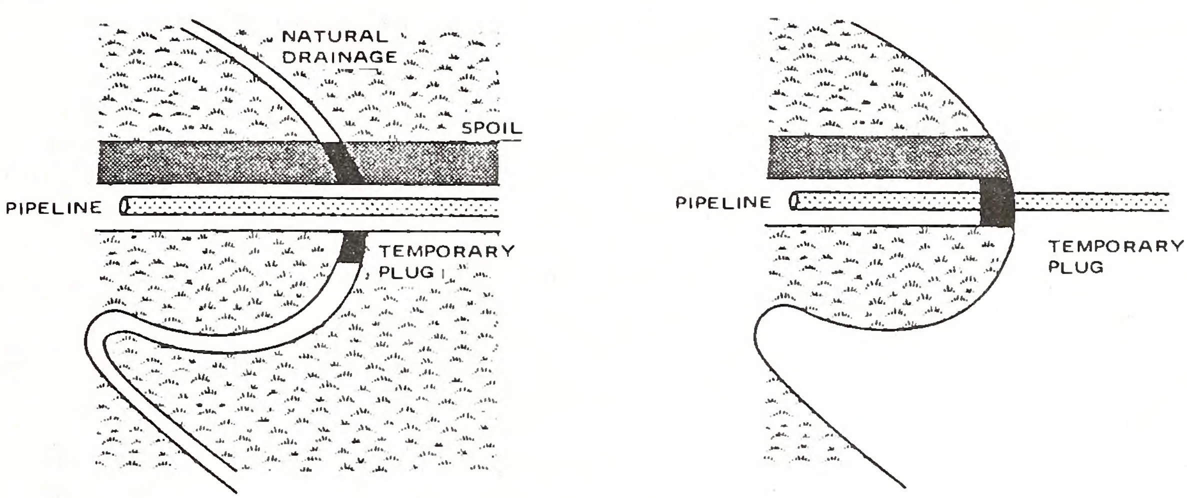


Figure 7-2. Locations of temporary plugs during wetland crossings.

4) Wooden mats or other support should be used to minimize marsh compaction and churning of the soil. Mats have generally been required by the Office of Coastal Management for work on North Carolina marshes.

Restoration. Requirements by regulatory agencies in Louisiana for amelioration of pipeline canal impacts and restoration of disturbed areas have increased substantially in the past 10-15 years as understanding of the importance of marsh systems has improved. Moreover, requirements are likely to become increasingly demanding as more experience is gained in restoration methods. If present trends continue, within a few years cleanup standards can be expected to require restoration of the marsh both geologically and ecologically to virtually original conditions.

The most elementary and important steps in restoring a pipeline canal area to its original condition, steps that have been required in Louisiana for the last decade, are the installation of plugs in the canal at intervals to eliminate water flow and boat use, and the creation of breaks in continuous spoil banks to allow tidal flow and freshwater runoff over the marsh. These steps are essential if detrimental hydrologic changes are to be avoided. Standard plugs consist of an earthern base, often with a bulkhead at the center, covered with a filter cloth or nylon cloth mesh and a layer of oyster or clam shells, topped off with a layer of large stones or rip-rap. In some cases the rip-rap is replaced with a porous mat (commercially known as Ercomat) that permits grasses to grow up through the covering and stabilize the plug (Dunham, 1981; Burke, 1981).

Plugs are placed at intervals along the canal (every 500 feet for the Louisiana Offshore Oil Port's pipeline canal), changing the canal from a continuous watercourse to a series of linear ponds. Plugs must be built above the marsh surface to prevent exchanges of water along the canal.

More substantial plugs, usually made of shell and rock (Figure 7-3) are used at waterway crossings. Plugs must be placed and designed to resist washing out; where shoreline erosion is a problem, they may be set 50 to 100 feet back from the bank so as to last longer. In any case, the plug must be broad enough to resist erosion, and must be tied well into the natural levee or bank to prevent water from cutting around it.

A second step, now commonly required in the Gulf, is to backfill the canal with the dredged spoil. A problem frequently encountered is that the stockpiled spoil shrinks in volume as a result of compaction and oxidation, the more so if marsh sediments are soft and runny and/or high in organic content. As a result, there is rarely enough spoil to completely refill the trench. Depending on water levels in the marsh, these long, shallow depressions may contain standing water. Often vegetation invades these shallow ponds, and in time they may fill in and become indistinguishable from the rest of the marsh. On the other hand, the danger also exists that these depressions will widen and deepen with time.

The amount of shrinkage can be reduced by minimizing the time between dredging and backfilling during which the spoil is exposed. However, complete backfilling usually will require that additional material be brought in from elsewhere. Both the North Carolina Office of Coastal Management and the Wilmington office of the Corps generally require marsh excavations to be

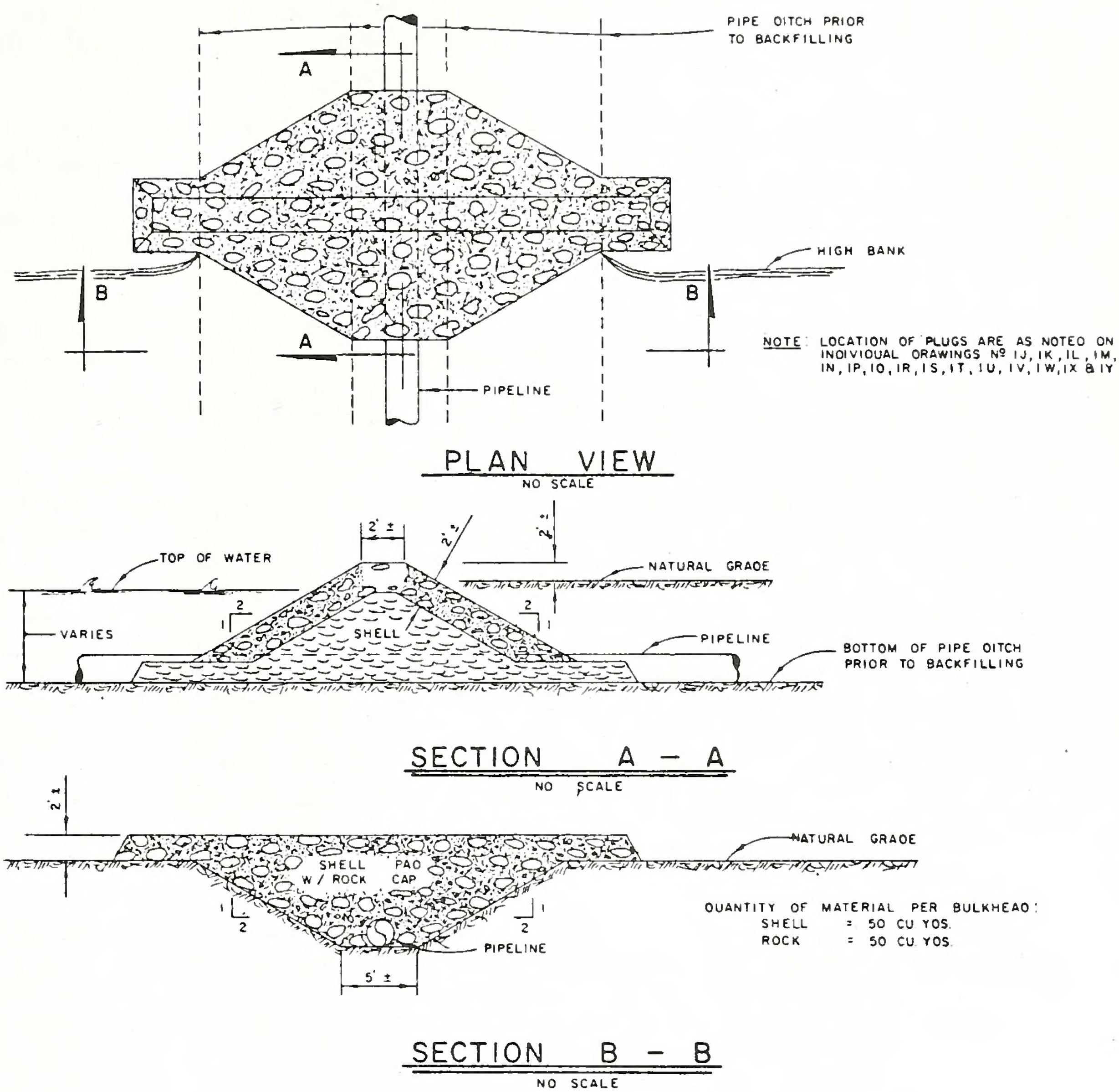


Figure 7-3. Canal plug used in some wetland installations. (Source: Gowen and Goetz, 1981, originally courtesy of Tennessee Gas Pipeline Co.)

backfilled to the original elevation, with additional material if necessary. Usually this material must be brought from high ground, although it may be dredged from sub-tidal bottomland if the area will soon be dredged for other purposes. The material used should be similar to the original substrate, and preferably should be placed into the trench first, and the marsh spoil placed on top.

Marsh sediments generally contain sufficient rhizomes and seeds for vegetation to reestablish itself. However, where sediments on the backfilled canal surface are not of marsh origin, or where for some other reason rapid natural revegetation is not expected, then the backfilled area and other areas where vegetation was eliminated by construction activities should be replanted.

Substantial experience in restoring and creating coastal marshes has been gained in the last 15 years, particularly in North Carolina. A team of researchers at North Carolina State University, led by William Woodhouse, Ernest Seneca, and Stephen Broome, have conducted a series of field trials and experiments on the North Carolina coast (see, e.g., Woodhouse et al., 1974, 1976b; Woodhouse, 1979). In the estimation of one of them (Seneca, 1982), there should be no major problems in restoring most wetland types that might be crossed by pipelines, provided certain lessons are observed. Time of year is critical. Best planting success is achieved when planting is begun in late March and early April. Backfilled sediments should have several weeks to settle and stabilize before planting, pushing the latest date for project completion back to February. Elevation is also critical, and should duplicate as nearly as possible the original marsh. The best success to date has been with Spartina alternifolia, and experience has shown that this marsh type usually can be restored to near pre-project conditions in two years, although the faunal component will take longer to re-establish. Methods are now being developed for other types (e.g., Juncus, S. cynosuroides) and restoration of these marsh types will probably take 3-5 years.

7.3 BARRIER ISLANDS

A narrow string of barrier islands stretches along virtually the entire North Carolina coast, from Currituck Banks in the north to Sunset Beach and Bird Island in the south. A substantial portion of this string lies within the boundaries of Cape Hatteras and Cape Lookout National Seashores, and parts of several other islands are protected in various units of the North Carolina State Parks system. In other areas, intensive vacation home and resort development has occurred, particularly in New Hanover, Carteret, and northern Dare Counties. North Carolina's barrier islands have become the focus of a great deal of attention as development pressures on the remaining natural areas have intensified and as more has been learned about the natural dynamics of barrier islands. Recent general accounts of these islands may be found in Alden et al., 1976; Leatherman, 1979a; and Pilkey et al., 1980. More specific studies are reported in Godfrey and Godfrey, 1976; Leatherman, 1979b; and a host of other sources.

Several distinct environments commonly occur on barrier islands (Figure 7-4). Approaching an island from offshore, one first encounters the nearshore and beach zones, where incoming waves break and dissipate their energy. Inland from the beach a row of primary dunes often forms, and behind it a dune

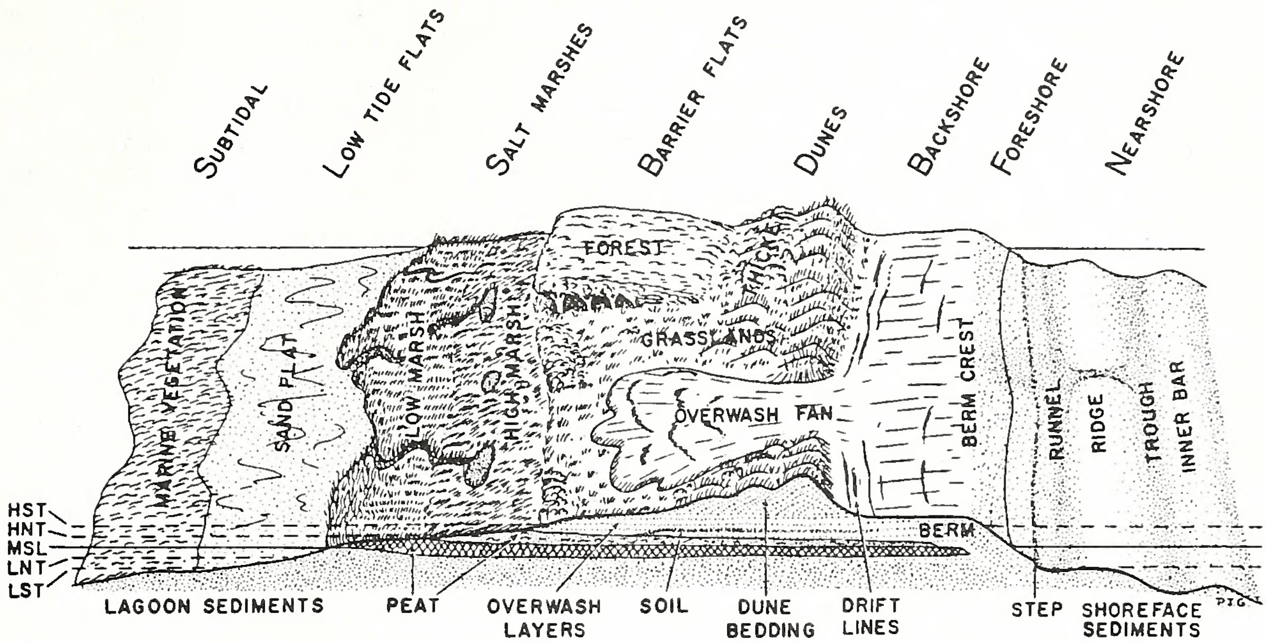


Figure 7-4. Barrier island environments. (from Leatherman, 1979a)

field may stretch inland for some distance. Dunes form under the influence of prevailing winds and vegetation. They are naturally dynamic landforms that change in height and position in response to storm waves, winds, vegetative cover and other factors. The nearshore sediments, beach, and primary dunes together form a dynamic, integrated unit within which sediment is redistributed in response to varying wave energy regimes. Often behind the dunes an area of negligible relief occurs known as a barrier flat, usually produced by overwash. The amount and type of vegetation on the flat varies with the degree of protection from overwash and salt spray, ranging from perennial grasses to shrub thickets and maritime forest. These flats give way on the sound side of the island to marshes and tidal flats, which may occur in abundance in the protected back-barrier environment.

There are several considerations in choosing both a pipeline route across a barrier island and the construction methods to be employed. Some of these considerations are based on concern for the pipeline's integrity, in light of hazards presented by shoreline erosion and inlet migration and formation. These concerns were addressed earlier in Chapter VI. Pipeline operators will also be concerned with such features as the availability of land and power for

aboveground facilities and the availability of road access to the site. Still other considerations are based on the sensitivity of barrier island environments and of human activities on the islands to disruption by pipeline construction. Of particular concern are: 1) disruption of the natural beach/dune environment, particularly removal or destabilization of the frontal dunes; 2) interference with the recreational use of barrier beaches; 3) inadvertent destruction of sea turtle nests; 4) various impacts on areas intensively developed for vacation homes and resort use; 5) disturbance of the relatively unique back island plant communities, particularly maritime forest; and 6) disturbance of the sound side marshes and tidal flats. Concerns 2, 3, 4, and 6 are discussed in general terms elsewhere in this report. The other two considerations are examined in some detail below, following which a discussion of the various factors to be considered in siting pipelines across barrier islands is presented.

7.3.1 Beaches and Dunes

Beaches and dunes serve several important functions in barrier island systems. First, they dissipate and absorb the force of waves and wind, of particular value during intense storms. The frontal dune row and backshore portion of the beach normally act as a sediment reservoir, releasing sediment during storms that is transported to nearshore areas, flattening the beach profile and so providing a wider area on which to dissipate wave energy. During fair weather, sand is transported back onshore to rebuild the back beach and frontal dune. In addition, dunes present a temporary line of defense against flooding during coastal storms, and in their natural state also provide various wildlife and aesthetic values.

The importance of these environments, and particularly the frontal dunes, in protecting back island environments has received increasing recognition in the last few years. A recent report for the New Jersey Department of Environmental Protection, for instance, recommended the establishment of a Dune Management District within which activities that might impair the natural protective function of dunes would be prohibited (Gares et al., 1979). In North Carolina, one of the categories of Areas of Environmental Concern established under CAMA is the ocean hazard area, defined to include three specific AECs: 1) the ocean erodible area, defined as the area on oceanfront coasts from mean low water to a distance, measured inland from the seaward line of stable natural vegetation, of either 60 feet or 30 times the long-term annual erosion rate, whichever is greater; 2) the high hazard flood area, being that area subject to high velocity flood waters from a 100-year storm; and 3) the inlet hazard area, which is those inlet lands that may be subjected to excessive erosion rates as a result of inlet migration. Pipeline construction within any of these areas will require a major development permit from the Coastal Resources Commission (CRC). One of the major objectives of the CRC in regulating development within this area is maintenance of the protective value of the frontal dunes (15 N.C.A.C. 7H .0303).

Pipeline construction methods employed at beach and dune landfalls were described in Chapter III, and a fuller discussion may be found in Gowen and Goetz (1981). The methods apt to be employed raise several concerns. Most worrisome is that there will be no frontal dune present during construction to protect inland areas, and that following construction, attempts to fully restore the dune system to pre-construction conditions may fail. This can

lead to blowouts in the dune line, more rapid dune migration, and/or increased washover frequency, endangering both natural areas and development (including the pipeline itself) on the back side of the island. A lesser concern is that sand disturbed during construction may be transported off the site, by wind or water, becoming a nuisance or reducing the available backfill.

To minimize these problems, several objectives for pipeline work in beach and dune environments should be established. These are:

1) to minimize the size and area of dunes to be altered;
2) to stabilize sand surfaces during construction;
3) to restore the area, and particularly the dune system, as near to pre-construction conditions as possible, both geomorphically, ecologically and visually.

Measures that can be used to achieve each of these objectives are discussed below. For the most part, the dunes along the North Carolina coast are not exceptionally large, the tallest in the frontal row rising perhaps 20-25 feet above mean high water. There appears to exist adequate understanding and technology to prevent any serious environmental harm as a result of pipeline installation, provided special care is exercised in the landfall's selection and construction.

The most obvious means to minimize the size and area of the dunes to be affected is to choose a landfall where dunes are either non-existent or low and eroded. Such conditions are common on the North Carolina coast; they may be found where development has eliminated the frontal dunes, where recent washovers have removed them, or where natural conditions of sand transport do not favor dune establishment. Sheet-pile retaining walls should be used to support the pipeline trench. Since the low angle of repose of loose sand causes unsupported trenches to be very wide, sheet pile can significantly reduce the width of the construction right-of-way needed through dunes, as well as reduce the volume of sand that must be stockpiled elsewhere. Finally, the construction area can also be fenced in to restrict the movement of construction vehicles, which have been shown in some cases to cause as much environmental damage as excavation of the pipeline trench itself (Ritchie and Walton, 1975).

Depending on the exposure of the landfall site, it may be necessary to stabilize the stockpiled sand and dune cuts during construction to prevent wind and water erosion of these surfaces. Large amounts of sand are generated during trench excavation and dune removal, for which there are several options for storage. The sand may be stored on the backshore portion of the beach or behind the dunes, or it may be used to construct a temporary coffer dam into the surf zone to support dredging equipment for the pipeline trench. No location is ideal. Back-dune storage offers the most protection from wind and wave erosion, but this area is often the most heavily vegetated. In some cases the sand is used to construct needed onshore causeways or work areas, and this offers the most efficient use of the material.

Stabilization of sand piles and dune cuts can be accomplished with netting, vegetation, clay-rich soil, plastic sheeting, fences, thatch, or stabilizing chemicals (such as Crelawn, a water-based, biodegradable bitumin compound used successfully at other pipeline landfalls). Fencing also can be used to prevent sand from blowing off the construction site, particularly near areas sensitive to blowing sand, such as residential neighborhoods and golf courses.

Restoration of the nearshore and beach zones is relatively simple. The trench is refilled with excavated material, the sheet piling is removed, and the site is graded to its original contours. Because of wave action, aesthetic recovery of the beach is relatively quick, although functionally the beach may be more vulnerable to wave erosion until natural resorting restores the sediments to equilibrium conditions (Gowen and Goetz, 1981). What few studies have been done suggest that the biotic community (bivalves, diatoms, tardigrades, etc.) recovers rapidly as well (Riedl and McMahan, 1974).

The primary objective in restoring dunes is to re-establish the dune's protective function, but in a manner that also restores as nearly as possible the dune's natural geomorphic and ecological processes. These include sediment exchange with the nearshore and beach zones, dune migration, and the effects of soil structure and water retention on dune vegetation. A number of techniques have been used at various pipeline landfalls in the U.S. and Great Britain to restore dunes removed during construction. These include:

- double-ditching; i.e., the removal, storage and replacement of the top 25 cm or so of the dune separately from the underlying sand;
- reconstruction of the dune landform using earth-moving equipment and/or sand fences;
- use of different materials (clay, gravel, evergreen brush, etc.) to stabilize internal dune structure, and other materials (thatching, fencing, chemical compounds) to stabilize the dune surface until vegetation becomes established;
- fertilization and/or addition of topsoil to dune sand to hasten revegetation; and
- reseeding or replanting of vegetation (the latter on seaward dune faces). (Ritchie, 1974; Golden et al., 1980; Gowen and Goetz, 1981)

There have been several recent pipeline crossings of Padre Island National Seashore, a long, low barrier island off the coast of Texas, and the Seashore's experience is instructive. In each case the National Park Service and the pipeline companies worked together to choose a pipeline route and construction guidelines acceptable to both parties. The primary consideration in selecting the landfall site was development of the foredune system; areas with very low foredune development, as a result of recent overwash or other causes, were preferred. Park Service personnel staked off the work area, making clear where construction vehicles were not permitted. Dunes were not rebuilt with bulldozers following installation, as experience had shown that dunes constructed in this manner were too draughty for plants to establish successfully. Would-be dune areas were planted with beach croton and sea oats in accordance with recent research on the island. Plantings were timed to coincide with the rainy seasons from September-November and February-March. Now in their second or third growing seasons, the plantings are doing very well, and some are showing 1/2 meter of dune development after three years (Woods, 1982). Both Park Service biologists contacted expressed satisfaction with the success of restoration efforts, noting that the crossing sites now were only barely visible.

A group of researchers at North Carolina State University, led by William Woodhouse, Ernest Seneca, and Stephen Broome, has developed substantial expertise in restoring dunes along the North Carolina coast (see e.g.,

Woodhouse et al., 1976a; Woodhouse, 1978; Seneca, 1980). The opinion of one of them (Seneca, 1982) is that dune restoration at pipeline landfalls in North Carolina should present no major difficulties, provided the results of the research done by them and others are applied. These include:

1) The way the dunes are reconstructed is important. As at Padre Island, dunes built with bulldozers have sand too coarse to hold water for plant use. Following backfilling, plants should be planted directly on the graded surface, or if time permits, short (2 ft.) sand fences can be used to accumulate sand for several months before planting.

2) The timing of planting is important: late fall and late winter plantings appear to work well, and planting should be completed by early March.

3) Planting stock used should be taken from as near the site as possible. This requires planning to begin at least a year ahead of time, to allow for the growing of stock not commercially available.

Directional drilling, described in Chapter III in connection with river crossings, offers some promise for avoiding the disruption of beach/dune landfall construction altogether. A drilling site could be established on the back side of an island, and the pipeline bored under the dunes, beach, and nearshore out to depths where a lay barge could continue pipelaying or conduct the tie-in. Not only would the beach and dunes be unharmed by this operation, but the technique would also permit substantially greater burial depths, a distinct advantage along erosion-prone shorelines. Directional drilling has not yet been tried at a landfall, however, both for reasons of expense, and because the technology for larger lines (24 in. and greater) is unproven.

7.3.2 Maritime Forest

Maritime forest may be found on the wider portions of North Carolina barrier islands, behind the dunes on the relatively sheltered barrier flats and relict dune ridges. Its composition and form are shaped by salt spray blowing inland from the ocean beaches: the forest is basically a variant of the coastal evergreen forest, from which many species have been removed by salt stress and the surviving species trimmed and sculpted by salt damage to growing branch tips. The dominant tree species in relatively undisturbed areas are usually live oak, laurel oak, and yaupon, with common associates including wax myrtle, red cedar, red bay, and American holly. Outstanding examples of maritime forest may be found in Duck Woods, Nags Head Woods, Buxton Woods, Ocracoke Island, Portsmouth, and on portions of Core Banks, Shackleford Bank, Bogue Banks, Bear Island, and Smith Island (Bellis and Proffitt, 1976). Studies of North Carolina maritime forest have been reported by Boyce (1954), Oosting (1954), Bourdeau and Oosting (1959), Brown (1959), and Cooper and Satterthwaite (1964).

Maritime forest contributes in important ways to both natural barrier island processes and human enjoyment of the island environment. The amount of remaining natural forest is quite limited; Bellis and Proffitt (1976) estimate that the land area occupied by maritime forest within the state is probably smaller than that of any other important coastal ecosystem. The relative uniqueness of these stands of vegetation and the wildlife habitat they provide confers a substantial value on them. Other functions include their aesthetic value, the protection they provide for structures and human activities against frequent strong winds, stabilization of loose sandy soils,

and conservation of scarce nutrients (potassium, calcium) provided by salt spray and rain.

The major impact of pipeline construction through maritime forest will be the loss of forest within the right-of-way. Within the permanent right-of-way, this loss will persist for both the service life of the pipeline and the time after that needed for the forest to regenerate. Given the salt stress and potentially unstable sandy soils of these areas, regeneration may take substantially longer than for other forest types in more protected sites.

Pipeline impacts on maritime forest can be minimized by avoiding such areas altogether or keeping crossings to a minimum. Where crossings are necessary, existing roads and other rights-of-way and disturbed areas should be used as much as possible. A recent study of the impacts of highway construction on maritime forest in North Carolina (Seneca and Broome, 1981) found that significant vegetation dieback occurred on the sound side of a road cut paralleling the shoreline, but not on the ocean side, presumably as a result of the interception of wind-borne salt by the leading edge of the forest (Figure 7-5). Their study suggests several untested hypotheses, phrased below as recommendations, for siting pipelines through maritime forest so as to minimize dieback beyond the right-of-way. These include: 1) avoid routes paralleling the beach, which expose one side of the cut to the full force of salt-laden winds; 2) if such a parallel cut is necessary, keep it as narrow as possible to reduce the amount of wind deflected into the opening, and locate the cut where salt spray is at a minimum, usually near the sound side of an island (Figure 7-6); and 3) erect and maintain sand fencing on the leeward edge of the right-of-way, as the study found that such fencing may reduce the amount of salt spray entering the forest.

7.3.3 Siting Considerations for Barrier Island Crossings

Two of the major considerations in siting pipeline crossings of barrier islands have been discussed above, and a number of others have been discussed under different headings elsewhere in this report. At this point it may be helpful to summarize these various concerns. In reviewing them, keep in mind that there is, of course, no reason for a pipeline to directly cross a barrier island. The pipeline can be routed along or diagonally across the island where the most advantageous oceanside landfall does not lie opposite the most advantageous soundside landfall, although there is a tradeoff in terms of increasing the area of disturbance and the pipeline's exposure to the unstable barrier island environment. These various considerations are:

1) The oceanside landfall should be chosen where the dunes, and particularly the foredunes, are nonexistent or low and eroded, so as to minimize the reduction in hazard protection resulting from pipeline construction.

2) The oceanside landfall should be chosen at a point where erosion rates are historically low, to minimize the danger that shoreline erosion will expose the pipeline.

3) Heavily used sea turtle nesting beaches should be avoided in season (May-October), and precautions taken on other beaches to avoid nest destruction.

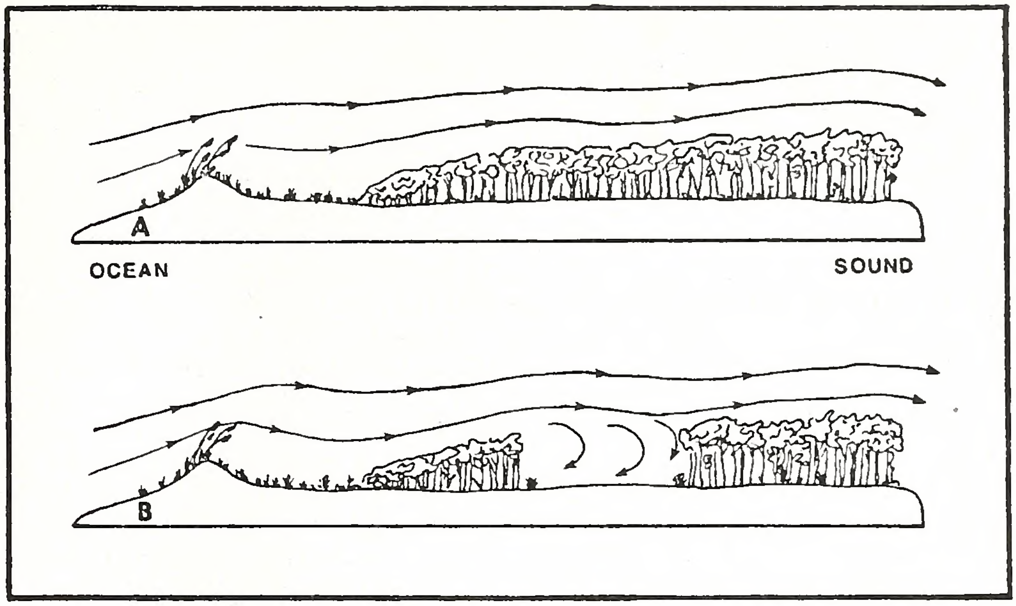


Figure 7-5. Generalized patterns of onshore winds across barrier island forest: (A) undisturbed, without a road, and (B) disturbed, with a road. (Source: Seneca and Broome, 1981)

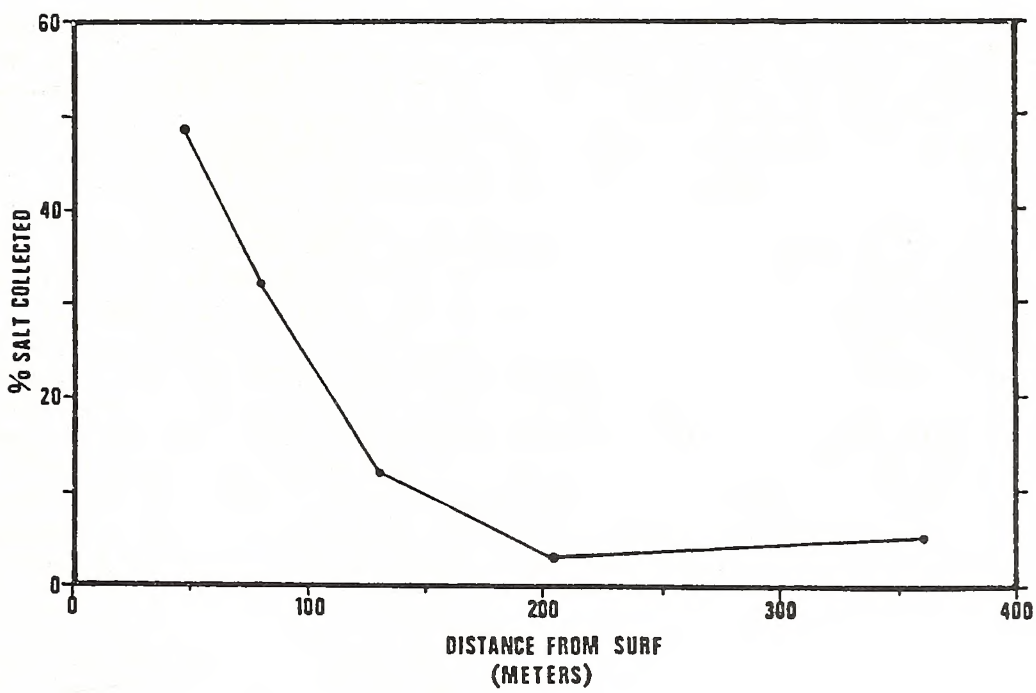


Figure 7-6. Percentage of salt spray collected at increasing distances from the surf through a stand of undisturbed maritime forest. (Source: Seneca and Broome, 1981)

4) Maritime forest, being a relatively rare and unique environment that provides positive aesthetic, recreational, soil-stabilizing, and ecological values, should be avoided to the greatest extent practical.

5) The pipeline crossing site should not have a history of overwash or inlet formation, as either of these events could expose and rupture the pipeline.

6) If the route crosses a heavily used recreational area, construction should be conducted during the off-season and restoration completed before the beginning of the next tourist season.

7) Heavily developed areas should be avoided, at least during the peak season of May to October.

8) Concentrations of valuable estuarine resources on the sound side of the island should be avoided, particularly wetlands, which tend to occur as a band of varying thickness on the island's back side, but also shellfish areas, grass beds, and colonial bird nesting sites, all of which may occur in close proximity to barrier islands. Barrier beach nesting sites, of which Parnell and Soots (1979) found several in 1977 occupied by black skimmers and four species of terns, should also be avoided.

Sources. The references mentioned above can serve as entrances to the literature. We are unaware of any surveys of significant dune areas or maritime forest in North Carolina.

7.4 OFFSHORE WATERS

Except in the event of an oil spill, pipeline activities will have very little effect on the surface and mid-water environment of the Carolina shelf, and impacts (largely due to construction) will be concentrated in the bottom few feet of the water column and upper few feet of sediment. For this reason, the following discussion will focus on the impacts of pipeline construction on the benthos and demersal nekton of that region.

The overall distribution of benthic and demersal organisms on the Carolina shelf appears to be regulated primarily by sediment conditions and temperature (Roberts, 1974). A number of recent papers review the literature on the biota of this region (see the relevant chapters in Saila, 1973; VIMS, 1974; and CNA, 1977, 1979), and two major papers in particular are responsible for much of what is known about the distribution of benthos. Cerame-Vivas and Gray (1966) described the distribution of benthic fauna on the North Carolina shelf in relation to water masses and the Hatteras discontinuity. They divided the more than 200 species they recorded into three assemblages: a Virginian fauna found on the inner shelf north of Cape Hatteras, a Carolinian fauna on the inner shelf south of Hatteras, and a tropical or Caribbean fauna offshore of both of these provinces over the outer half of the shelf.

Day et al. (1971) examined the infauna at ten stations along a 40-mile transect extending east from Cape Lookout to the 200 meter contour. Their analysis showed that, in addition to a distinctive but poor open beach community, three subtidal, sand-bottom faunistic zones or assemblages could be distinguished: a turbulent zone in 3 to 20 meters of water that was dominated by the sand dollar Mellita quinquiesperforata, its commensal crab Dissodactylus mellitae, and a variety of polychaetes, amphipods, Olivella gastropods, the surf clam Spisula ravenelli, and the archiannelid Polygordius; an outer shelf fauna in waters 40 to 120 meters deep dominated by polychaetes

and in which species of amphipods, mysids, and scaphopods are also common; and an upper slope fauna in 120 to 200 meters of water which again is dominated by polychaetes and includes several characteristic amphipods, scaphopods, and pelecypods.

A rather unique soft-bottom, open-shelf benthic community -- calico scallop beds -- was studied by Schwartz and Porter (1977). They examined the physical and chemical environment, fish and macroinvertebrate faunas, possible predators, and ecological relationships of several beds south of Beaufort. Though they documented the interesting faunal assemblage associated with these beds, they were unable to identify any physical, chemical or biological factors that would explain the beds' peculiarly patchy distribution and productivity.

Scattered across the continental shelf south of Cape Hatteras are a series of hard grounds or "live bottoms" of various origin. They are common in Onslow Bay, where there is little sediment supply and the sediment cover over underlying rock is consequently thin and patchy, and much less common in Raleigh Bay to the north and Long Bay to the south, where the sediment supply from coastal plain rivers is much more substantial (Mixon and Pilkey, 1976).

Studies of the geology and biology of hard bottoms on the shelf off North Carolina have been conducted by a number of researchers. A thorough review of the literature on these areas was provided by Continental Shelf Associates (1979). The subjects of individual studies have included:

- outcrops of Trent Marl with a reefal cap 4-5" thick of sessile snails and tubicolous annelids, in 4-17 meters of water off New River Inlet (Pearse and Williams, 1951);
- nearshore bands of coquina limestone in less than 15 meters of water in all three bays, and extensive phosphate limestone outcrops extending across central Onslow Bay from Frying Pan Shoals to Lookout Shoals (Milliman et al., 1968);
- the "infauna" associated with heads of the scleractinian coral <u>Oculina arbuscula</u> collected in 3-25 meters of water in the vicinity of Beaufort (McCloskey, 1970);
- a small, 3 km^2 area of large broken ledges and isolated boulders rising abruptly from sandy sediments in 16-27 meters of water 18 km northeast of Cape Hatteras, and dominated by scleractinian corals and molluscs (Duke University Marine Laboratory (DUML), 1981);
- a series of coral patches in Onslow Bay, characterized by individual heads of two species of reef or hermatypic coral, <u>Solenastrea hydades</u> and <u>Siderastrea siderea</u>, several species of ahermatypic coral, and a variety of sea fans, sponges, algae and other epiphytic organisms (Macintyre and Pilkey, 1969b; Macintyre, 1970; Huntsman and Macintyre, 1971); some of these appear to be part of an extensive area of several hundred km^2 in 29-37 meters of water east of Cape Fear, with little or no sediment cover and a lush biota of algae, molluscs, decapods, echinoids, and sponges (DUML, 1981);
- the marine benthic flora of the Carolina shelf, collected mainly from outcrops in the middle and outer portions of Onslow Bay (Schneider, 1976); and
- a series of discontinuous ridges and terraces in 50-150 meters parallel to the shelf break between Cape Hatteras and Cape Fear, showing local relief of up to 15 meters, and consisting of highly bored algal limestone (thought to have been laid down 12,000-15,000 years ago at a lower stage of

sea level by the calcareous marine alga Lithothamnion and other calcareous epifauna) and calcareous sandstone. Biological studies on part of this system have delineated three faunal components: an upper-reef, sandy fauna dominated by the bivalve Glycymeris, an epifaunal reef assemblage of echinoids, gorgonians, hydroids and bryozoans, and a lower reef sand-mud assemblage. (Menzies et al., 1966; Macintyre and Milliman, 1970; Cain, 1972; Mixon and Pilkey, 1976; DUML, 1981).

Several studies of the demersal fish resources of the continental shelf have been conducted. Struhsaker (1969) reported the results of a five-year study of demersal fish on the shelf between Cape Hatteras, North Carolina, and Jupiter, Florida. On the basis of study results, the continental shelf was divided into five regions: 1) coastal (15-18 m), 2) open shelf (18-55 m), 3) live bottom, 4) shelf edge (55-110 m), and 5) lower shelf (110-183 m). Trawl catches in the open shelf zone were generally poor. Live bottom and shelf edge habitats were far more productive, providing moderate to large catches of snappers, groupers and porgies in certain localities.

Table 7-2 reports the composition of demersal fish populations that were either collected or observed in the vicinity of hard bottoms or wrecks in Onslow Bay (Huntsman and Macintyre, 1971), or collected over hard bottom during extensive trawling between Cape Fear and Cape Canaveral (Barans and Burrell, 1976). Research conducted in recent years by the Atlantic Estuarine Fisheries Center at Beaufort on the reef fishes of the Carolina shelf and the recreational fisheries that exploit them have added much to our knowledge of these groups (see, e.g., Huntsman, 1976; Grimes et al., 1977; Manooch et al., 1981).

The impacts of pipelines on these resources are difficult to estimate. The major resources affected will be benthic communities and, because all of the commercial species that spawn offshore have pelagic eggs and larvae, the juvenile and adult members of demersal fish stocks. Primary sources of impact will be 1) direct disturbance of the seafloor and 2) long-term habitat alteration, regarding both of which, unfortunately, there is a dearth of studies in the OCS region.

Very little impact will result if the pipeline is simply laid on the seafloor. The anchors of the lay barge will create some disturbance (unless it is equipped with a dynamic positioning system), and the pipeline itself, associated anchors and span supports will destroy a few organisms underneath and suspend insignificant amounts of sediment. On the other hand, the unburied pipeline will provide additional hard substrate for the development of a biofouling community, and over the long-term, the pipeline may act as a small artificial reef, enhancing biological productivity along the route.

Burial of the pipeline will create substantially greater disturbance. In unconsolidated sediments, the width of the trench and the volume of sediment that must be removed depends on sediment characteristics: clays will hold narrow trenches with vertical walls, while trenches of sufficient depth in loose, sandy sediments (more common on the North Carolina shelf) will have a relatively wide, shallow profile. Even with a wide trench, however, the area disturbed offshore will be relatively insignificant, and certainly no greater than that disturbed by other activities and natural events, such as bottom trawling, scallop dredging, and submarine slumps. No studies were found that

Table 7-2. Fishes commonly associated with hard bottom habitats on the continental shelf of the southeastern United States. (Revised from Continental Shelf Associates, 1979)

Taxa	H + M[1]	B + B[2]
Abudefduf saxatilis - sergeant major	X	
Alutera scripta - scrawled filefish	X	
Calamus leucosteus - whitebone porgy		X
Calamus penna - sheephead porgy	X	
Caranx latus - horse-eye jack	X	
Caranx ruber - bar jack	X	
Centropristis striata - black sea bass		X
Chaetodipterus faber - atlantic spadefish	X	
Chaetodon sp. - butterflyfish	X	X
Chromis enchrysura - yellowtail reeffish		X
Doratonotus megalepis - dwarf wrasse	X	
Epinephelus drummondhayi - snowy grouper		X
Epinephelus niveatus - gag		X
Equetus acuminatus - cubbyu	X	
Equetus lanceolatus - jackknife fish	X	
Eupomacentrus leucostictus - beaugregory	X	
Haemulon aurolineatum - tomtate	X	X
Haemulon plumieri - white grunt	X	X
Holocanthus ciliaris - queen angelfish	X	
Holocanthus bermudensis - blue angelfish	X	X
Holocentrus bullisi - deepwater squirrelfish		X
Hypoplectrus unicolor - butter hamlet	X	
Lachnolaimus maximus - hogfish	X	
Lagodon rhonboides - pinfish		X
Lutjanus campechanus - red snapper	X	X
Mycteroperca microlepsis -gag	X	X
Mycteroperca phenax - scamp	X	X
Pagrus sedecim - red porgy		X
Rhomboplites aurorubens - vermilion snapper	X	X
Seriola dumerili - greater amberjack	X	
Sphyraena barracuda - great barracuda	X	
Thallassoma bifasciatum - bluehead	X	
Xyrichthys psittacus - pearly razorfish	X	

[1] Huntsman and Macintyre, 1971
[2] Barans and Burrell, 1976

dealt with the recovery time of disturbed sediments offshore, but because of the relatively more stable physical environment, one would expect recovery to take longer than in estuaries.

A more substantial impact is apt to occur in areas of rock outcrops and reefs where the pipeline is buried or the bottom altered to provide a flatter topographic profile. Depending on the degree of substrate induration, trenching by conventional means may not be possible, and burial will only be feasible if excavation is done with blasting. The use of explosives will destroy or injure many organisms in the vicinity as well as alter the physical habitat, often by reducing local relief. Given the absence of any studies of these effects, however, it is difficult to predict such impacts in any quantitative way.

Stipulation No. 2, attached to all Sale 56 leases by BLM (now MMS), requires that a bathymetric map of the lease block, with interpretations for live bottom areas within 1820 feet of activity sites (including pipeline placement), be submitted as part of every exploration or development plan. Furthermore, MMS may require "any measure deemed economically, environmentally, and technically feasible to protect live bottom areas," including both relocation of the activity and monitoring to assess the adequacy of mitigation measures applied and of the impact of the lessee's activities. The stipulation only applies to the lease blocks themselves, however; biologically sensitive areas elsewhere on the shelf, including hard grounds, will receive consideration under the requirements for environmental review of MMS pipeline right-of-way grants set forth at 43 C.F.R. §3340.

In view of the higher productivity of hard bottoms and the absence of knowledge about other specific offshore areas of high biological productivity or sensitivity, the following siting criteria are recommended for offshore waters:

1) Where burial is necessary for pipeline protection and stability, hard or live bottoms should be avoided and the pipeline routed through areas with sufficient sediment cover for burial (at least 2-3 meters). If hard bottoms must be crossed, the route should be chosen to minimize the crossing distance, and should also avoid areas of high relief, high fishing pressure, and other indications of high productivity.

2) Where burial is not required for safety and stability, pipelines crossing hard bottoms should not be buried.

Where reefs must be crossed and environmental damage results, an appropriate mitigation measure would be construction of an artificial reef at company expense.

7.5 RARE AND ENDANGERED SPECIES

The populations of a number of plant and animal species in North Carolina are either rare, threatened, or endangered and are afforded varying degrees of protection under state and federal law. Some of the potential impacts of pipelines on these species will be regulated directly under these laws, while other impacts may be considered in the more broad-based environmental reviews conducted by MMS, FERC and others.

The Federal Endangered Species Act of 1973 (16 U.S.C. §1531) is the most significant piece of endangered species legislation and offers the greatest degree of protection. The act's key provision, Section 7, requires that "each Federal agency shall, in consultation with and with the assistance of the Secretary [of the Interior], insure that any action authorized, funded, or carried out by such agency...does not jeopardize the continued existence of any endangered species or threatened species...unless such agency has been granted an exemption for such action..." Pipeline construction will involve several federal actions that will in turn require Section 7 consultation. These include the granting of a right-of-way by MMS, Section 10 and 404 permits by the Corps, and for a gas pipeline, a certificate of public convenience and necessity by FERC.

The most recent publication of the federal list of threatened and endangered species identifies the following species that are known to or may occur in eastern North Carolina or offshore waters (50 C.F.R. §17.11):

Species	Status
Blue whale (Balaenoptera musculus)	E
Finback whale (Balaenoptera physalus)	E
Sei whale (Balaenoptera borealis)	E
Humpback whale (Megaptera novaeangliae)	E
Right whale (Balaena glacialis)	E
Sperm whale (Physeter catodon)	T
West Indian manatee (Trichechus manatus)	E
Shortnose sturgeon (Acipenser brevirostrum)	E
Atlantic Ridley sea turtle (Lepidochelys kempii)	E
Hawksbill sea turtle (Eretmochelys imbricata)	E
Leatherback sea turtle (Dermochelys coriacea)	E
Green sea turtle (Chelonia mydas)	T
Loggerhead sea turtle (Caretta caretta)	T
American alligator (Alligator mississippiensis)	E
Panther (Felis concolor coryi)	E
Brown pelican (Pelecanus occidentalis)	E
Bald eagle (Haliaeetus leucocephalus)	E
Peregrine falcon (Falco peregrinus anatum and tundrius)	E
Red-cockaded woodpecker (Picoides borealis)	E
Bachman's warbler (Vermivora bachmanii)	E
Kirtland's warbler (Dendroica kirtlandii)	E

Key: E = Endangered   T = Threatened

Jurisdiction over the various species is divided between the U.S. Fish and Wildlife Service (USFWS) and the National Marine Fisheries Service (NMFS). For North Carolina, the USFWS office in Asheville is responsible for Section 7 consultations covering all terrestrial species, the West Indian manatee, and sea turtles while they are on land. Consultations on marine mammals, sea turtles in the water, and anadromous fish are handled by the NMFS office in St. Petersburg, Fla.

Though plant species also may be protected under the Endangered Species Act, no plant species occurring in the North Carolina coastal plain are currently on the federal list. An extensive list of plant species being considered for threatened or endangered status was published by the Fish and Wildlife Service in the Federal Register on Dec. 15, 1980 (45 F.R. 82480 ff., 1980). A number of these species occur in eastern North Carolina. Though these species are not protected as yet under the Act, the Federal Register notice states that "such taxa should be considered in environmental planning." It is expected that most of the better candidates from this list will go through the listing process during the next five years (Smith, 1981).

Several North Carolina laws offer varying degrees of protection to rare plant and animal species. Under the authority of several statutes, the Wildlife Resources Commission established a list of threatened and endangered species and declared that "it is unlawful to take or possess any of such species at any time," with certain exceptions (15 N.C.A.C. 10I .0002). Currently this list is identical to the federal list for animal species in North Carolina. Though the WRC regulation is applicable to all government and private actions, the range of actions prohibited is much narrower than that of the federal act, in that only the taking or possession of individuals is prohibited, and not the destruction of habitat.

The North Carolina Plant Protection and Conservation Act (G.S. §§106-202.1 to 202.8), passed in 1979, established a North Carolina Plant Conservation Board, authorized to adopt lists of endangered and threatened plant species within North Carolina. Thirteen species known or thought to occur within the twenty coastal counties were included in the most recent listing (N.C. Protected Plant List, July 1, 1981). Though it is unofficially requested that these taxa be considered in environmental planning, the only statutory protection these species are entitled to is that they may not be removed from the land of someone other than the landowner without the owner's permission, nor may they be sold, bartered, traded, exchanged or given away, without permission of the Plant Conservation Board. It is unlikely that either this statute or the Wildlife Resources Commission regulations would influence pipelaying activities significantly.

Finally, under the Coastal Area Management Act, "areas that support native plants or animals determined to be rare or endangered (synonymous with threatened and endangered) within the coastal area" (15 N.C.A.C. 7H .0505) may be designated as Areas of Environmental Concern. To date, however, no AECs in this category have been designated.

The impacts of pipelaying on endangered and threatened species will depend in general on the route chosen, the time of year of construction, and the construction and restoration methods used. For many species, the choice of route location will be the most significant factor determining the degree of impact. Where a species is limited by a scarcity of critical habitat, such habitat is best avoided, unless construction and complete restoration can be accomplished during a portion of the year when the habitat is not used. Timing may also be important, for many species only occupy certain habitats on a seasonal basis, or their susceptibility to disturbance varies during the course of a year. The extent of pipelaying impacts also will be determined by the choice of construction and restoration methods, and in some cases these can be chosen to minimize impacts on nearby individuals. Pipelaying impacts

will be highly species-specific, and appropriate mitigation measures will need to be worked out with USFWS and NMFS for each species potentially affected.

The distribution and abundance of whales and sea turtles in North Carolina waters are poorly known. There are no recorded sitings of the blue whale off the southeast Atlantic coast. Of the other five whales, occurrence of right, fin, and humpback whales off North Carolina appears to be seasonal and related to their annual migrations (Schmidly, 1981).

Any impacts of pipelaying on whales are most likely to occur during trenching operations, when turbidity, noise and other effects may disrupt feeding behavior. Disturbed individuals probably will simply move to other feeding areas, and since pipelaying is only a one-time event of relatively short duration, significant adverse impacts appear unlikely (USDOI/BLM, 1981b). A potential exception is the use of blasting to excavate a trench through consolidated materials. Though blasting's impact on whales is not fully known, it has been the practice of NMFS to require a spotting survey before the blast to assure that no whales are in the vicinity (Mager, 1982).

Of the five federally-listed sea turtles, the Atlantic Loggerhead nests regularly on North Carolina beaches and may be found throughout the state's ocean and sound waters. The other four appear to be occasional residents of the state, but are not known to nest here (Schwartz, 1977).

As with whales, the feeding behavior of turtles may be temporarily disrupted by pipelaying activities. Turtles rely extensively on live bottoms for foraging, and where either blasting or sedimentation associated with pipelaying operations destroys live bottom, turtle food supplies will be reduced. Since blasting may also injure turtles directly, a spotting survey before blasting to assure the absence of nearby turtles would be appropriate. To the extent that any unburied portions of the line act as artificial reefs, however, turtle food supplies may be increased.

Of greater concern with turtles is the impact of pipeline landfall construction on turtle nesting. Field studies by the N.C. Wildlife Resources Commission in 1980 and 1981 found Loggerhead nesting activity on most of the state's oceanfront beaches. Activity was greatest in the south and varied substantially among the beaches surveyed. The nesting season in North Carolina runs approximately from early June through mid-August, but nests have been reported in late May and late August. Since Loggerhead eggs have an incubation period of 55-70 days, there is a risk of disturbing turtle nests with landfall construction anytime between late May and late October. Scheduling landfall work for November to May would be the simplest way of avoiding impacts and would be especially preferable in areas of heavy nesting activity. Where not possible, other mitigation measures may be feasible; as part of their Shallowbag Bay project, the Corps has agreed to relocate any turtle nests discovered (Merdock, 1981).

There are two nesting colonies of brown pelicans in North Carolina, one in the Cape Fear River, the other on a small island near Ocracoke Inlet. In addition, there appears to be a large and growing non-breeding summer population, and a third breeding colony may form within the next few years. The state's wintering population numbers roughly 2500 birds, scattered along the coast from South Carolina to Oregon Inlet (Parnell, 1981). Though it would

be impossible to completely avoid all impact on pelicans, at certain times and places the population is particularly vulnerable to disturbance, and these occasions deserve special consideration. Most important are the breeding colonies, which are occupied from March into September. Nearby disturbance during this period could very well reduce reproductive success, and these colonies should be given wide berth by pipeline operations. Though little is known about the bird's major winter roosting sites, these may also play an important role in pelican survival. In addition, pelicans are sight feeders, so that turbidity created by dredging and trenching operations may reduce their foraging efficiency. This last factor will be especially important during the breeding season, when colony residents do most of their foraging within a few miles of the colony, and during late winter, when pelican mortality is high and food availability is critical for survival (Parnell, 1981).

The red-cockaded woodpecker may be found in many of North Carolina's coastal counties, wherever the bird's exacting habitat requirements for mature pine woodlands with little understory are met. Major woodpecker concentrations occur at Fort Bragg, Sandhills Game Land, Croatan National Forest, and Sunny Point Military Ocean Terminal (Parnell and Committee, 1977; Merdock, 1981). The only significant threat to these birds from pipeline construction would be the loss of the birds' pinewoods habitat within the right-of-way. Since the woodpecker may travel up to a half mile from its nest to forage, right-of-way clearing through the bird's habitat within a half mile of a nest site will probably have an adverse impact on the species. The best solution would be to avoid this habitat type regardless of known woodpecker occupation. Where a right-of-way through potential woodpecker habitat is proposed, it has been the general practice of USFWS to require that a mile-wide swath along the right-of-way be surveyed to assure the absence of these birds and their nesting cavities (Merdock, 1981).

The American alligator reaches the northern limit of its range on the south shore of Albemarle Sound. Found in coastal rivers, lakes, marshes and estuaries, its preferred habitat in North Carolina seems to be the larger coastal river systems and canals. The primary threats to the species from pipelaying are habitat destruction within the right-of-way itself, and alterations in water flow that may reduce habitat suitability beyond the right-of-way. Where sufficient vacant habitat occurs nearby, alligators within the right-of-way can often be encouraged to move without harm. The species is most sensitive to disturbance during the nesting season (spring and summer) (Merdock, 1981; Palmer and Braswell, 1977).

Peregrine falcons migrate through the state, and they and bald eagles occasionally overwinter here, but it is unlikely that pipelaying would have any impact on either species. Should either begin nesting here, however (there was one reported eagle nesting attempt in Dare Co. in 1979), then nests would, of course, have to be avoided. The other species on the federal list (manatee, shortnose sturgeon, panther, Bachman's and Kirtland's warblers) occur so rarely and irregularly here as to make any anticipation of pipelaying impacts nearly impossible. There have been no confirmed sitings of several of these species for a number of years.

Sources: Further information on these and other species of concern may be found in Cooper et al. (1977), Schmidly (1981), and USDOI/BLM (1981c). The

state's Natural Heritage Program in the Department of Natural Resources and Community Development in Raleigh maintains the most extensive inventory available of sitings and locations of North Carolina rare and endangered species.

7.6 WILDLIFE

The diverse environments of eastern North Carolina support a wide variety of game and non-game wildlife. Deer, rabbits and squirrels are plentiful and popular game species. Bear are found in several parts of the coastal plain, but only in extensive natural tracts relatively free of human habitation. A number of furbearers may be found: raccoon, opposum, red and gray fox, and in the marshes, rivers and sounds, muskrat, otter, mink, nutria, and beaver. Bobwhite quail, mourning doves, woodcock, and rails are popular game birds, and turkeys are making a modest comeback, though still restricted in numbers. The coastal area is also important for several groups of migratory birds. Waterfowl winter in the coastal bays in large numbers, the beaches and intertidal flats are important stopover points for shorebirds, and a number of colonial waterbirds nest along the coast (Wilson, 1962; Barick and Critcher, 1975).

The primary mechanism requiring consideration of the pipeline's impact on these wildlife resources is the Federal Fish and Wildlife Coordination Act (16 U.S.C. §§661 et seq.). Enacted "to provide that wildlife conservation shall receive equal consideration and be coordinated with other features of water-resource development programs," the law requires consultation with both the U.S. Fish and Wildlife Service and the state fish and game agency (in North Carolina, the Wildlife Resources Commission) regarding any federally funded or licensed activities in streams and other water bodies. Consultation is to be conducted "with a view to the conservation of wildlife resources by preventing loss of and damage to such resources as well as providing for the development and improvement thereof in connection with such water-resource development."

An additional degree of statutory protection for wildlife is derived from the various laws and regulations governing pipeline construction in National Wildlife Refuges, National Parks, and other natural areas, and from the Endangered Species Act (see sections on Outstanding Natural Areas, Wildlife Refuges and Game Lands, and Rare and Endangered Species).

The impact of pipeline construction on wildlife will vary with the particular environment and species being considered, but several general observations are possible. The only wildlife use of the offshore environment is by pelagic birds (shearwaters, petrels, and others), while other groups of birds (waterfowl and waders) and several mammals (otter, muskrat and others) utilize the nearshore shallows. The primary wildlife impact of pipelaying in these environments will be the temporary decrease in food supply resulting from bottom disturbance and turbidity. The effect will be very minor offshore, where birds feed only in the upper few feet of the water column. Closer to shore, wildlife exploit benthic plant and animal populations, the water volume available to dilute suspended sediments is much less, and the area of bottom disturbed may be much greater as a result of flotation canal dredging. Here the effect on wildlife will be greater, but in most instances still will be relatively minor or of short duration.

The major cause of wildlife impacts in terrestrial environments will be the removal of all vegetation within the right-of-way and subsequent establishment of a new and often different plant community. During clearing operations there will be a loss of animals with limited mobility: reptiles, amphibians, rodents, shrews, moles, and the young of various birds and mammals. In addition, some of those displaced may perish for lack of suitable adjacent habitat (FPC, 1977). The noise, smells and activities associated with construction will inhibit reproduction of many species within a band wider than the right-of-way (USDOI, 1976).

Until vegetation is re-established, there will be a complete loss of potential food crops within the right-of-way. Any decline in soil fertility will depress productivity over longer periods of time.

The greatest impact will occur where pipeline construction causes habitat change that persists over the life of the project or even longer. The conversion of forest to herbaceous and shrub communities is the most common example of this type, but persistent habitat alteration may also occur in environments difficult to restore (some types of marshes?) and where other pipeline impacts, such as alterations in the hydrologic regime, cause habitat change that extends beyond the right-of-way. Where long-term habitat changes do occur, species will fare differently depending on their habitat requirements. For instance, the loss of habitat for woodland species, such as squirrels and woodland birds, will be offset to some extent by a gain in open and edge habitat preferred by deer and rabbits. Under certain circumstances, the change in habitat types could have beneficial effects on wildlife populations, as when relatively sterile pine plantations are broken up by rights-of-way that provide more herbaceous cover and edge. In very general terms, wildlife populations will benefit where pipeline construction increases habitat diversity, and will suffer where diversity is decreased. For the most part, though, impacts will be relatively small and localized.

Wildlife will also be affected by maintenance operations, particularly measures taken to suppress the growth of trees and large brush whose roots may damage the pipeline. If brush-cutting machinery is used in the spring and early summer, there will be considerable losses of ground-nesting birds and small mammals. Herbicides, on the other hand, have a number of deleterious effects, not only on animals within the right-of-way, but also on those in adjacent drift areas and on aquatic species in waterways receiving herbicide-laden runoff (USDOI, 1976). In addition, hunting pressure may increase as a result of access provided by the right-of-way.

These impacts will be greatest where the pipeline route crosses productive habitats, either where large concentrations of wildlife occur, or that are in relatively short supply. Threatened and endangered species' habitats are one example, and these have been discussed in another section. Other habitats in these categories include the nesting sites of colonial waterbirds, wintering waterfowl habitat, gum-cypress swamps, and several others. These areas deserve special consideration in pipeline planning.

<u>Colonial Waterbird Nesting</u>. Of the North Carolina bird species that are closely associated with aquatic habitats, more than twenty nest in aggregations of a few to several thousand pairs. These include pelicans, cormorants, herons, egrets, ibises, gulls, terns and skimmers. All but

Table 7-3. Summary of period of colony occupation with an indication of the peak of incubation for colonial waterbirds nesting in North Carolina. (Source: Parnell and Soots, 1979)

Species	Period of Colony Occupation	Peak of Incubation: Southeastern N. C.	Peak of Incubation: Northeastern N. C.	Incubation Period[2] (days)
Brown Pelican	March to Sept.	NA[1]	NA[1]	28
Great Egret	March to Aug.	15-30 Apr.	1-15 May	23-24
Snowy Egret	April to Sept.	1-15 May	7-21 May	21-24
Louisiana Heron	April to Sept.	1-15 May	1-15 May	23-25
Little Blue Heron	April to Sept.	15-30 Apr.	7-21 May	22-25
Green Heron	April to Aug.	15-30 Apr.	1-15 May	19-21
Black-crowned Night Heron	March to Aug.	15-30 Apr.	1-15 May	24-26
Cattle Egret	April to Oct.	1-15 May[1]	15-30 May[1]	22-23
Glossy Ibis	April to Sept.	1-15 May	7-21 May	21
White Ibis	March to Aug.	15-30 Apr.	NA[3]	21-23
Herring Gull	May to Sept.	NA[3]	1-15 June	26
Great Black-backed Gull	May to Sept.	NA[3]	1-15 June	26-28
Laughing Gull	April to Aug.	20-31 May	7-21 June	20
Gull-billed Tern	May to Aug.	20-31 May	1-15 June	22-23
Forster's Tern	May to Aug.	NA[2]	1-15 June	23
Common Tern	May to Sept.	21 May-7 June	1-15 June	21
Least Tern	April to Sept.	21 May-15 June	1-15 June	19
Royal Tern	April to Aug.	7-21 May	15-25 May	30-31
Sandwich Tern	April to Aug.	7-21 May	15-25 May	20-23
Caspian Tern	May to Aug.	NA[3]	15-25 May	20
Black Skimmer	May to Oct.	1-15 June[1]	1-15 June[1]	23-25

[1] Nesting period prolonged, initiation of incubation erratic, several censuses required.
[2] Species does not nest in this sector.
[3] Incubation periods referenced in species accounts.

cormorants characteristically nest on islands within estuaries or on barrier beaches.

A survey in 1977 by Parnell and Soots (1979) of nesting colonies of these birds in coastal North Carolina recorded over 51,000 pairs of 23 species at roughly 125 sites. The survey found high concentrations of birds within small areas, and it was not uncommon to find single sites where 20-40% of the censused breeding population of that species in the state was breeding. Such large concentrations of individuals make these species particularly sensitive to disturbance. For this reason, pipelaying should avoid these sites at least during the nesting season, which generally runs from early spring to late summer (see Table 7-3). Pipeline installation in the Laguna Madre in Texas is prohibited during the nesting season and within 500 ft. of nesting sites during the rest of the year (Woods, 1982).

Waterfowl Wintering Areas. A substantial portion of the waterfowl in the Atlantic flyway overwinters in coastal North Carolina (see Table 7-4). The tremendous quantities of food annually produced in the shallow waters of Currituck Sound and portions of the Pamlico and Perquimans Rivers make these areas especially important to waterfowl. Other coastal waters of value to waterfowl, as ranked by Wilson (1962) in order of descending importance, are

Table 7-4. Average winter waterfowl population, by water body, 1978-1982.

Water Body	Dabbling Ducks	Diving Ducks	Other Ducks	Geese	Swans	Coot	Total
Currituck Sound and tributaries	40,300	5,400	-	21,200	8,000	18,600	93,500
Albemarle Sound and tributaries	3,700	3,300	-	6,100	2,000	1,600	16,800
Dare County	3,700	12,300	5,700	6,100	800	700	29,300
Pungo, Phelps and Mattamuskeet Lakes	47,100	1,400	100	24,600	17,400	100	90,700
Pamlico Sound	15,500	35,500	5,300	13,800	1,500	9,900	81,400
Pamlico and Pungo Rivers	900	22,000	1,100	1,100	800	1,200	27,000
Swanquarter National Wildlife Refuge	1,000	31,300	1,000	1,600	1,200	100	36,100
Neuse River	1,700	51,800	1,300	-	-	-	54,700
Croatan National Forest Lakes (Great, Long, Little, Ellis, and Catfish)	1,500	1,800	-	100	300	500	4,300
Core Sound	800	20,100	400	600	-	800	22,600
New River and coastal sounds from Cape Lookout to Cape Fear	600	2,400	200	-	-	100	3,300
Cape Fear River and coastal sounds from Cape Fear to South Carolina	1,000	200	-	-	-	1,000	2,200
Remainder of state	2,900	700	200	900	600	100	5,400
North Carolina state total	120,600	188,200	15,300	76,100	32,600	34,700	467,300

Note: "-" indicates an average count of less that fifty birds

Source: Compiled from survey summary sheets of the Mid-Winter Waterfowl Survey conducted by the U.S. Fish Wildlife Service.

Pamlico, Core and Bogue Sounds; numerous small sounds, inlets and bays; and Albemarle Sound. Certain inland waters also support large waterfowl concentrations. Lake Mattamuskeet, for instance, each winter hosts roughly one fifth of the North American population of whistling swans, as well as tens of thousands of ducks and geese (Riley and Riley, 1979).

Pipelaying during the winter months (November to March) should avoid the areas of heaviest waterfowl concentrations. Consideration also should be given to the shortest crossing of waterfowl feeding areas, and to restoration of preferred waterfowl food supplies (e.g., sago pondweed and wild celery) destroyed during pipelaying operations.

Other Habitats. Several other relatively limited habitats are of particular wildlife value and should receive special consideration in route and construction planning (Critcher, 1981). These include gum-cypress swamps

(habitat for mink, otter, beaver, raccoon, deer, bear and waterfowl; principal wood duck nesting habitat), inland marshes (wintering and breeding waterfowl habitat), streambanks and bottomland hardwoods (particularly in intensively farmed areas where strips of creekside vegetation are the only available cover for a wide variety of wildlife), and, to a lesser extent, maritime forests.

Several measures can be taken to minimize the adverse impacts of pipelaying on wildlife. Most important are route selection and the timing of construction. The route should be chosen to avoid major wildlife production and concentration areas, at least while they are being used. Rights-of-way through productive forested areas should also be minimized because of the resulting long-term changes in habitat. The use of existing rights-of-way will eliminate many wildlife concerns and is a persistent recommendation of wildlife biologists. To the extent possible, construction and maintenance operations should also be scheduled to avoid the seasons of peak use for a particular habitat, be it spring and summer in breeding areas, winter in wintering areas, or spring and fall at migratory stopover points.

A host of small-scale adjustments in route, timing, and construction methods also can be made to reduce local disturbances. These might include selecting the best alignment for river crossings or relocating an access road to bypass a raptor nest. Regarding these, early and close consultation between the pipeline company and state and federal wildlife biologists is strongly encouraged. Different institutional arrangements for this consultation should be considered; the Joint Fish and Wildlife Advisory Team formed during construction of the Trans-Alaska Pipeline provides one model. Morehouse et al. (1978) examined the operation and effectiveness of that team, as well as other aspects of fish and wildlife protection during construction of the pipeline, and offer a number of useful suggestions.

Revegetation can play an important role in mitigating wildlife impacts. The soil should be stabilized with mulches, stabilizers and vegetation as soon as possible to minimize erosion. Tree and shrub plantings selected for their wildlife food and cover values should be planted in the construction right-of-way to restore wildlife and aesthetic values rapidly (USDOI, 1976). For the permanent right-of-way, the choice of herbs and shrubs should also be made with wildlife species in mind. In Alberta, for instance, pipeline rights-of-way have been planted with staggered blocks of browse species to provide both food and security for deer while still permitting maintenance access (Figure 7-7) (Stubbs and Markham, 1979). Asplundh Environmental Services (1979) has recently compiled an extensive reference manual on the management of transmission line rights-of-way for fish and wildlife, and much of the information they provide is also applicable to pipeline rights-of-way.

Sources. Information on bird populations and habits tends to be more complete than for other wildlife groups. The best general references are Pearson et al. (1959), Potter et al. (1980), and the chapters on coastal birds provided in the various continental shelf environmental summaries (Heppner and Gould, 1973; Adamus and Drury, 1977; Forsythe and Adamus, 1979). Population surveys of several types are available for specific areas, including the annual Christmas Bird Counts conducted under the auspices of the National Audubon Society (published in American Birds), the Breeding Bird Surveys and Winter Waterfowl Surveys conducted annually by the Office of Migratory Bird Management, U.S. Fish and Wildlife Service, and the 1977 survey by Parnell and

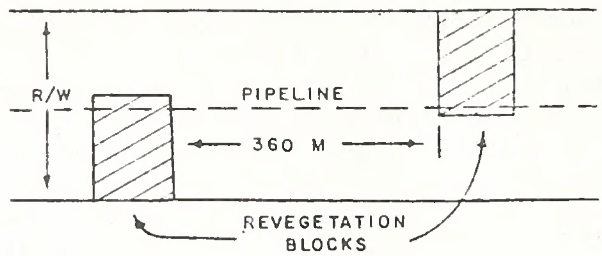


Figure 7-7. By planting palatable browse species in staggered blocks, a pipeline right-of-way can provide security and food for wild ungulates. (from Stubbs and Markham, 1979)

Soots (1979) of colonial waterbird colonies. The Office of Biological Services, U.S. Fish and Wildlife Service, has funded a major literature review of marine birds of the southeastern Atlantic and Gulf coasts of the U.S. to provide information on avian distribution, life histories, and susceptiblity to oil pollution. The first volume, covering loons, grebes, cormorants, pelicans and pelagic species, was published in March of 1982 (Clapp et al., 1982); a second volume on waterfowl should be available in late 1982, and a final volume on gulls, terns and shorebirds at a later date.

Generalized map information on wildlife species and groups in coastal North Carolina is available from several sources: the Atlantic Coast Ecological Inventory published by the U.S. Fish and Wildlife Service (Beccasio et al., 1980); coastal county maps of wildlife habitat in Barick and Critcher (1975); and distribution maps of certain game species compiled by the Wildlife Resources Commission. Cooper et al. (1977) provide species accounts of a number of rare and endangered wildlife species in North Carolina. The state's Land Resources Information System computerized data base includes waterfowl wintering and breeding areas and colonial bird rookeries. The files of the N.C. Natural Heritage Program contain data on a number of wildlife areas. Additional sources of information are the personnel and files of the N.C. State Museum of Natural History, the Wildlife Resources Commission, and various universities.

7.7 FRESHWATER RESOURCES

Several major rivers drain into North Carolina coastal waters, including the Chowan, Roanoke, Tar/Pamlico, Neuse and Cape Fear, and both these and the coastal sounds are fed by a dense network of smaller tributary streams and creeks. Streams in the relatively flat eastern coastal plain tend to be sluggish, with silty or sandy bottoms high in organic matter, and often surrounded by gum-cypress or hardwood swamp forests. Lakes are rare, but several occur on the peninsula between Albemarle and Pamlico Sounds and in Croatan National Forest.

Many coastal streams support substantial game fish populations. Most of the catch in coastal counties consists of various sunfishes (bluegill, redbreast, flier, warmouth and crappie), white perch, and yellow perch. Largemouth bass is highly prized but constitutes only a small portion of the

take; other species caught with less frequency include striped bass, pickerel, and shad (Barick and Critcher, 1975).

Construction of pipelines across rivers and streams was reviewed in Section 3.2.2.2; typical procedure involves excavation of a pipeline trench in the river bottom and movement of the pre-assembled pipe string into place by either the bottom pull or floating bridge method. Pipeline construction across or near streams and lakes may have several adverse impacts on these resources, including increased turbidity and sedimentation, water quality degradation, disruption of surface drainage, and interference with other stream uses.

Turbidity and Sedimentation. The most serious pipeline impact will be high levels of turbidity and sedimentation generated by instream construction activities during waterway crossings, and by accelerated soil erosion from the right-of-way (particularly stream banks), staging areas, access roads, borrow pits, and other disturbed areas. Additional sources of sediment may include stream erosion caused by uncontrolled discharges of hydrostatic test water, and erosion of the channel floor due to the removal of vegetation, the use of finer backfill material, and upstream cutting caused by a break in streambed slope (USDOI, 1976).

High turbidities have been shown to have a number of effects on fish and aquatic invertebrates, including interference with respiration, abrasion of the gills, pathological changes to gill structures, changes in blood chemistry, and disruption of migration (Allen and Hardy, 1980). Photosynthesis is also reduced in turbid water. However, there is little evidence that river dredging (such as occurs during pipeline installations) causes significant problems of these types. The turbidity generated is not only temporary, but usually less than the turbidity associated with natural flooding. For the most part, mobile organisms will vacate the site and not be directly harmed, though displaced organisms may succumb to a lack of suitable empty habitat. In lowland streams such as those in eastern North Carolina, high silt loads occur naturally and most organisms are able to survive periods of high turbidity.

Far more serious than high turbidity levels will be the effects of sedimentation on downstream benthic flora and fauna. Settling material will smother or stress benthic invertebrates and rooted aquatics. Populations of rare mussel species, which occur in a number of North Carolina streams (Cooper et al., 1977), may be reduced or eliminated. Changes may occur in bottom sediments that will alter habitat character and sharply extend recovery time, as when shifting sands blanket a silty organic bottom. Fish nests will be buried, and fish eggs suffocated.

The intensity, extent and duration of impact will depend on the amount and duration of sediment inputs, the type of sediment, the characteristics of the stream, and other factors. Waterway crossings generate a one-time slug of sediment during the period of construction, which may vary from a few days for a creek to 1-4 months for major rivers. If the crossing is short and the streambed and banks stabilize rapidly, the reach of stream affected is apt to be small and the sediments so dispersed as to have insignificant effects. Bottom silt loads will return to normal after a few periods of high stream flows. On the other hand, major stream crossings generate large amounts of

sediment over several months, and sedimentation from eroding stream banks and other areas may continue for years. In these cases, significant areas of stream bottom may be buried and the resident biota eliminated.

Riverine habitats buried under sediment have shown variable recovery times. In most cases, the area is repopulated in one or two growing seasons, although the initial fauna may be characterized by opportunistic species and low species diversity (Allen and Hardy, 1980). Fish generally repopulate the affected stretch rapidly from adjacent reaches of the stream. Where stream crossings or erosion sites introduce sediment into streams over a period of months or even years, however, greatly reduced aquatic populations may occur for several years over a limited stretch below the site.

A variety of measures are available to reduce the severity of these impacts. Some stream crossing locations are less disruptive than others, and guidelines for siting waterway crossings are presented at the end of this section. In addition, periods of fish migration and spawning should be avoided; in eastern North Carolina, the former occurs during the months of February through May, and the latter from late February through June. In relatively quiet waters, silt curtains can be hung downstream of the construction operation to filter out suspended sediments. The streambed trench preferably should be backfilled with the original spoil, but in no case should be filled with material finer or more erodible than the original sediments. Splash plates, flow control reservoirs, and other devices should be used to prevent erosion from the discharge of hydrostatic test water.

The amount and activity of instream construction equipment should be kept to a minimum, and efforts should be made to minimize erosion from the right-of-way, particularly stream banks. Potentially useful measures to accomplish this include: barriers to downslope water flow along the streambank trench, both before and after backfilling; the clearing of only the minimum amount of land necessary next to the stream; the use of erosion control devices such as diversion ditches and buffer strips to minimize sediment inputs to the stream from the staging area; and, of course, the rapid stabilization and revegetation of stream banks and other work surfaces.

The use of directionally-controlled, horizontal drilling for river crossings would eliminate most of the problems associated with traditional crossing techniques, and should be encouraged wherever feasible. Overhead pipeline crossings, while avoiding some of the adverse impacts of steambed crossings, present additional problems of their own.

Water Quality. A second major cause of concern with pipeline construction is degraded water quality. Potential causes of degradation include:

1) Diesel fuel and gasoline. Large quantities of these fuels are required during construction and will be concentrated at storage and distribution points. At these locations, a certain amount of spillage is inevitable, and spills elsewhere may result from vehicle accidents and careless work. Soil is an efficient absorber of petroleum, but small amounts may enter water bodies where they will produce a petroleum film on the water surface. Such films are highly destructive of aquatic microbiota but are not hazardous to larger, mobile species. Should a major spill enter a waterway, however, all aquatic life will be adversely affected (USDOI, 1976).

2) Chemical applications to the right-of-way. These include fertilizers, of whose constituents nitrogen is particularly mobile and known to contribute to eutrophication of water bodies, and herbicides of varying toxicities to aquatic life.

3) Dissolved solids. Higher loads of dissolved solids may enter surface waters as a result of the dissolving of fragmented backfill in the pipeline trench and of suspended sediments in the stream.

4) Toxic substances in stream sediments. Toxic substances in stream sediments may be released by bottom disturbing construction activities. These substances include both naturally occurring toxins, such as hydrogen sulfide, methane and ammonia, and various man-made wastes, including oils and greases, pesticides and heavy metals. Only a handful of potentially polluted sites are known within the state. Because the buffering capacity of salts is much less in fresh water than in estuarine waters, the hazard presented by substances such as heavy metals is greater (Allen and hardy, 1980).

5) Low dissolved oxygen concentrations. The disturbance of highly organic sediments during construction operations will lower dissolved oxygen concentrations downstream. The biota of such streams are generally adapted to low oxygen conditions, and such effects are apt to be significant only in extreme cases, such as in sluggish streams during the low flow period of late summer when water temperatures are high.

6) Contaminants of hydrostatic test water. Test water may contain small quantities of mud and welding slag that must be removed before the water is discharged. If the pipeline has been properly cleaned before testing, the concentrations of these contaminants in the test water should be insignificant.

7) Poor quality water from the pipeline trench. Water pumped from the pipeline trench to facilitate construction may be highly acidic, low in dissolved oxygen, or of poor quality in other respects. Such water should not be discharged directly to surface waters.

Several precautions can be taken to reduce the chance or degree of water quality degradation. The most important step is to minimize the use and eliminate the storage of materials such as gasoline, diesel fuel, herbicides and other toxic materials near surface waters. Where stream bottom sediments are suspected of being contaminated, testing should be done before construction begins, and where pollutants are present the pipeline should be rerouted or trench spoil fully contained. If necessary, hydrostatatic test water should be treated before discharge using a percolation pond or other means.

In addition to sediment inputs and other water quality degradation, there are several other sources of concern regarding pipeline construction:

1) Maintenance of lake levels and instream flow. The rate of water withdrawal for hydrostatic testing from streams should not exceed 5-10% of flow, nor, if taken from lakes, should it lower lake levels substantially. Construction across even small flowing streams should be done so as to maintain water flow.

2) Maintenance of surface drainage networks. The potential problems of surface drainage disruption were discussed in the section on soils. Proper care should be applied in marking and restoring drainage channels crossed by the pipeline trench.

3) Maintenance of groundwater levels and quality. Degradation of groundwater quality as a result of increased dissolved solids, fuel spills and

other causes is unlikely, if routine precautions are taken. The beheading of shallow aquifers can occur, as discussed in the section on inland wetlands, but is unlikely if the trench is properly refilled and other appropriate measures taken to eliminate drainage along the trench.

4) Interference with other uses of the stream or lake, particularly during the construction period. These may include: conflicts with recreational use of the site, including reduction of the fishery resource in the downstream reach; aesthetic degradation at the crossing and of areas experiencing increased turbidity; clogging of downstream water supply intakes, requiring backflushing operations; and interference with navigational use during both pipeline construction and operation. Several of these problems are discussed in greater detail in Chapter VIII.

The potential for water resources impacts will be reviewed by government agencies in connection with their various statutory responsibilities. Interstate gas lines are subject to FERC's guidelines for minimizing environmental damage listed at 18 C.F.R. §2.69. These include admonitions regarding stabilization of streambanks, use of cofferdams, prevention of oil spills and other pollution, withdrawal and discharge of hydrostatic test water, and use of blasting in streambeds. Most pipeline crossings will require a Section 404 permit from the Corps, and navigable waterway crossings will require a Section 10 permit as well. Like FERC's certificate, the application process for these permits entails a general environmental review, and a variety of federal and state environmental agencies will be asked to comment.

Two specific water quality permits may also be required. Discharges of hydrostatic test water will require a National Pollutant Discharge and Elimination System (NPDES) permit from the state, and probably a 401 Water Quality Certification as well (see Cribbins, 1981, for a discussion of these). To obtain the 401 Certification, certain measures may be needed to ensure that state suspended solids and turbidity standards for that particular stream segment are not exceeded.

A set of general guidelines for siting pipeline crossings of rivers and streams to minimize environmental damage can be drawn from the above discussion and that of several other sections in this report. By way of summary, these guidelines are presented here without any attempt to assign priorities or to recommend how tradeoffs should be made. These guidelines are:

1) Stream, river and lake crossings should be avoided whenever possible.

2) When a stream or river must be crossed, the route should be as near perpendicular to the stream course as possible, and at a narrow point.

3) Under virtually no circumstances should a pipeline be laid up or downstream within a riverbed, nor should it parallel a river on its bank.

4) Factors that should be involved in choosing river crossings include: a) expected ease of streambank restoration; b) use of the streambed at or below the crossing for fish spawning; c) other values and uses of the downstream river reach including rare and endangered species, productive game fish habitat, recreational use, aesthetic enjoyment, water supply and others; d) the presence of polluted sediments; e) stability of the stream channel and the depth of scour during floods; f) previous disturbance of the streambed; and g) the width of valuable riparian or floodplain habitat on either side that would also be crossed.

7.8 OUTSTANDING NATURAL AREAS

Scattered throughout the state's coastal zone are a variety of natural areas that possess distinctive ecological or geological characterisitics. Some are superb examples of relatively common ecosystem types or geomorphic features. Others contain rare species assemblages, unique geological formations, or individual endangered species. What these areas share is a recognition by scientists and others that their protection is important for illustrating and preserving North Carolina's natural heritage.

The impacts of pipeline construction on these areas cannot be generalized. The type and extent of impact will be specific to each area, and will depend on the natural processes of the area in question and on the construction and restoration methods employed. In some cases, pipeline construction may be fully compatible with an area's outstanding qualities. In other areas, it may be impossible for pipeline construction to avoid causing long-term disturbance or complete destruction of an area. The latter may occur through direct impacts within the right-of-way or through indirect effects on critical ecological or geological processes.

There are relatively few programs directed specifically at providing statutory protection for outstanding natural areas. The most notable example is the National Wilderness Preservation System, created by the Wilderness Act of 1964 (16 U.S.C. §§1131-1136, as amended). Section 4(c) of the act prohibits almost all commerical enterprises, roads, motor vehicles, structures and installations within wilderness areas, a ban that would include pipeline activities. Currently there is only one designated wilderness in eastern North Carolina: the Swanquarter Wilderness, comprising 9000 acres of the Swanquarter National Wildlife Refuge in southern Hyde County. Several other areas are being considered for wilderness designation. These include 12,990 acres on Shackleford Bank, Core Banks, and Portsmouth Island in Cape Lookout National Seashore, and four RARE II (Roadless Area Review and Evaluation) tracts in Croatan National Forest. (Following public hearings and further study, however, it appears that the Cape Lookout proposal may be pared down to include only Shackleford Bank, with the remaining Seashore areas to be managed as natural areas by the Park Service.)

Sanctuaries in coastal waters are authorized under two different provisions of federal law. The Federal Coastal Zone Management Act of 1972, as amended, (16 U.S.C. §§1451 et seq.) authorizes matching grants to states for the acquisition, development and operation of estuarine sanctuaries. The purpose of the sanctuaries program is to provide natural field laboratories, and multiple use of a sanctuary is allowed to the extent that such use is compatible with the sanctuary's primary purpose. North Carolina recently received a grant to begin acquisition of two sites as National Estuarine Sanctuaries: the Carrot Island complex (2025 acres) immediately south of Beaufort, and Zeke's Island complex (1650 acres) 6 miles north of Cape Fear. It is anticipated that two other sites, Masonboro Island and a tract on Currituck Banks, will be added to the system at a later date. The Marine Protection, Research, and Sanctuaries Act of 1972 (33 U.S.C. §§1401-1444; 16 U.S.C. §§1431-1434) authorizes the Secretary of Commerce to establish marine sanctuaries "for the purpose of preserving or restoring such areas for their conservation, recreational, ecological, or aesthetic values," and to issue regulations consistent with achieving these goals. One marine sanctuary (the

U.S.S. Monitor) has been designated off North Carolina and is discussed further in Section 8.7. Chelsea International Corp., under contract to the Department of Commerce, is in the process of developing a Site Evaluation List for future marine sanctuary candidates; the list is expected to be published in the Federal Register in February 1983 and may well contain one or more sites off North Carolina.

At the state level, Article XIV, Section 5 of the North Carolina Constitution, adopted in 1972, authorized the creation of a "State Nature and Historic Preserve" comprised of land parcels set aside to preserve their environmental and cultural values. In 1979, the General Assembly incorporated a number of state-owned areas into the Preserve (G.S. §143-260.10), including all of six coastal state parks, portions of two others, and several historic sites. Under Article XIV of the Constitution, such areas "shall not be used for other purposes [such as pipeline rights-of-way] except as authorized by law enacted by a vote of three-fifths of the members of each house of the General Assembly." Protection for natural areas is also available through the natural area categories of Areas of Environmental Concern (AEC) under CAMA. To date, however, no AECs have been designated within these categories (Coastal Areas That Sustain Remnant Species, Coastal Complex Natural Areas, and Unique Coastal Geologic Formations).

Only a small fraction of the natural areas in eastern North Carolina recognized as significant are protected under these programs. For the rest, preservation is dependent primarily on the management priorities of the areas' landowners, and to some extent on general recognition of the outstanding qualities of these areas. One of the most pressing needs in natural area protection is simply the identification of such areas so that their presence may be considered in environmental planning for development, including pipelines.

A sizeable number of programs exist for the purpose of identifying such areas, and, by providing recognition, hopefully encouraging preservation (Laist and Bigford, 1979). Perhaps the most exclusive and prestigious is the National Registry of Natural Landmarks, administered by the National Park Service. The program was established in 1962, under authority of the Historic Sites Act of 1935, "to identify and encourage the preservation of areas which represent nationally significant examples of the ecological and geological features of the Nation" (46 F.R. 51196, 1981; see 36 C.F.R. §62 for description of program policies and procedures). Of the 537 natural landmarks currently on the Registry, four are in North Carolina's coastal counties: Goose Creek State Park Natural Area (Beaufort Co.), Green Swamp (Brunswick Co.), Nags Head Woods and Jockey Ridge (Dare Co.), and Bear Island (Onslow Co.). Though no statutory protection accompanies listing in the Registry, the National Park Service suggests that "Federal agencies may wish to consider the location and significance of natural landmarks in project planning and environmental review" (46 F.R. 51196, 1981).

Comparable to the National Registry at the state level is the North Carolina Registry of Natural Heritage Areas. Like the National Registry, the North Carolina Registry seeks to encourage the preservation of significant natural areas through recognition, rather than through regulation or acquisition. However, the Registry's potential role in environmental planning

is limited by the fact that an area's owner must apply for and agree to inclusion on the Registry.

More representative of the outstanding natural features of the state is the Natural Heritage Areas Priority List, maintained by the North Carolina Natural Heritage Program and updated annually. It contains a list of what are judged to be the state's most significant natural areas, regardless of ownership. Features of primary concern are exemplary plant communities, geomorphic landforms, habitats of native plants and animals, rare or endangered species habitat, disjunct and/or relict ecological features, and essential breeding, wintering, or migratory areas for wildlife. On the 1981 list, 139 natural areas in the twenty coastal counties and the state's offshore waters were listed. As better information becomes available, it is expected that new areas will be added and some currently listed areas will be dropped.

In addition to the Registry and Priority List, the state's Natural Heritage Program maintains an extensive map and computer file of outstanding natural features within the state. Any proposed pipeline right-of-way should be checked against the Program's records to identify potential conflicts along the route. Unfortunately the files are far from complete, and the absence of records on a particular area offers no assurance that the area is devoid of significant natural features. In the coastal area, natural areas inventories for ten of the twenty counties have been or are being conducted under contract with the state's Coastal Energy Impact Program, and coverage for these areas will soon be among the most comprehensive in the state.

7.9 INLAND WETLANDS

Wilson (1962), Cooper et al. (1975), and Tomkovick (1976) describe three types of inland wetlands common in the eastern coastal plain of North Carolina:

1) Gum-cypress swamps. These swamps reach their best development on the floodplains of black water rivers and on flats associated with upland drainage channels, mostly within 60 miles of the coast. They are often flooded in winter by 1-4 feet of water, and standing water may occur throughout the growing season in years of heavy rainfall. The characteristic trees of these swamps are bald cypress (in the wetter sites), tupelo gum and swamp or black gum; other common trees include red maple, water ash, red bay and sweet bay. Swamp soils are normally peaty and the herbaceous layer almost absent as a result of the dense shade and wet conditions. A number of animals inhabit or visit these swamps for water, food or sanctuary, including squirrels, raccoons, mink, muskrat, bear, bobcat, wood ducks, and mallards. An extensive descriptive study of two swamp forests in northeastern North Carolina was conducted in the early 1970's by Pardue et al. (1975).

2) Hardwood swamp or floodplain forest. This forest type dominates the floodplains of the major through-flowing rivers of the coastal plain and their tributaries and is generally found 50 to 100 miles inland of the coast, with comparatively little acreage in the twenty coastal counties. These bottomlands are typically flooded only by periodic freshets and floods that result from the heavy rains of late winter and early spring, and during summer the silty, alluvial soils may be quite dry. The plant community is more

diverse than that of gum-cypress swamps, with many shrubs and herbs, while major species of the overstory include a variety of oaks (water, willow, and cherrybark, in particular), sweet gum, ash, sycamore, river birch, and elm. Bottomlands are valuable widlife habitat: the trees provide mast and dens for a variety of game animals, including squirrels, rabbits, raccoons, wood ducks, turkeys, mallards, minks, and muskrats. Hardwood swamps are also the most productive of coastal plain habitats for deer, supporting as many as 35-40 deer per square mile (Monschein, 1981).

3) Pocosins. Also known as bays or shrub bogs, pocosins occur over much of the eastern coastal plain, often in vast tracts. Their peat soils are waterlogged most of the year but rarely flooded, and the more acidic peats are particularly low in fertility. Pond pine is the only common tree, usually occurring in scattered, open stands; major shrubs include ti-ti, gallberry, fetter bush, honey cup, cane, and sweet pepperbush. Wildlife populations, including deer, rabbits, and several furbearers, tend to be low. Because of the vast size of some pocosins, these areas provide refuge for species that require large undisturbed tracts, such as black bear and possibly panther (Wilbur, 1981; Monschein, 1981). A recent symposium on the pocosin wetlands of eastern North Carolina examined the ecology, values and uses of these areas (Richardson, 1981).

Acreages for these three wetland types, based on surveys by Wilson (1962) in 1957-59, are shown in Table 7-5. Since then, the area of all three types has diminished, particularly that of pocosins, which are being developed for agriculture, forestry, peat mining and other uses. Richardson et al. (1981) used Landsat imagery, USGS quadrangles, aerial reconnaissance, and field checks to estimate the area of pocosins remaining in 1979. They determined that, of the 2.24 million acres of pocosins in eastern North Carolina found by Wilson in 1957-59, approximately 1.50 million acres (67%) remained in a natural or slightly altered condition twenty years later, while 0.74 million acres (33%) had been substantially altered or destroyed by development.

Table 7-5. Acreages of Inland Wetlands in the Twenty Coastal Counties in 1957-59. (from Wilson, 1962)

Wetland Type	Acreage	Percentage of Total Land Area
Gum-Cypress Swamp Forest	532,550	8.8%
Bottomland Hardwood Swamp Forest	40,900	0.7%
Pocosins	1,546,850	25.6%

There are several potential impacts of pipeline construction in these environments. Most likely and substantial will be the alteration of habitat within the right-of-way as a result of complete destruction of right-of-way vegetation during construction and the suppression of tree growth during pipeline operation. The impact will be greatest in swamps and bottomlands,

which tend to be heavily forested, provide valuable wildlife habitat, and are in relatively short supply in many areas. Pocosins, being more abundant, less productive, and possessing an open canopy, will be relatively less affected. With the continuing alteration of natural pocosins, however, there is growing concern that representative examples of the different pocosin types should be preserved (including some that are not abundant, such as Carolina Bays) (Taggart, 1981; Roe, 1981), and pipeline construction through these particular tracts will lower their value as natural preserves.

A second major concern is that pipeline construction will result in wetland drainage along the pipeline ditch, both during construction via the open ditch, and afterwards if the ditch is not backfilled fully or if the loose backfill is more permeable than the surrounding soil. Small perched wetlands, more common in the upper Midwest and Northeast than in eastern North Carolina, are particularly vulnerable (USDOI, 1976). For ground-table wetlands the effect will tend to be localized within a few meters of the ditch; in small wetlands such as Carolina Bays, however, this area may constitute a substantial portion of the wetland.

The amount of drainage that will occur is impossible to predict without information regarding hydrology, soil conditions, construction methods, and other details. In the more severe cases, drainage may be sufficient to eliminate standing water during portions of the year, lower the water table significantly, and cause shifts in vegetation and wildlife populations in the pipeline's vicinity. In this respect, the impacts of pipeline construction may be similar to those of various intentional drainage measures such as channelization, and studies of the latter are of some relevance.

Maki et al. (1980) compared the water table behavior and vegetation dynamics of four channelized and seven non-channelized streams in the eastern coastal plain of North Carolina, between Gates and Craven Counties. In general, they found that channelization caused a shift in vegetation from "water-loving" species (bald cypress, tupelo gum and black gum) to more mesic species (red maple, sweet gum, and oaks). There was no evidence of severe dieback or loss of vigor in the trees along the channelized streams except in the few observed instances where pools of stagnant water were held behind spoil banks or where several feet of spoil had been piled against the base of trees. Furthermore, the drier conditions at channelized sites produced a greater biomass of lesser vegetation (shrubs, vines and herbs), but this vegetation also competed with tree seedlings, resulting in four times as many small stems per hectare in non-channelized areas as in channelized ones.

Lollis (1981) combined observations of the sites studied by Maki et al. with known habitat preferences of a number of wildlife species to estimate the effects of channelization on wildlife. He concluded, not surprisingly, that channelization reduces the habitat for wetland species while improving it for upland wildlife. Animals most severly affected included mink, otter, and several species of amphibians and ducks, while ground-nesting and ground-dwelling mammals, birds and reptiles benefitted most from the change. Channelization of forested stream basins also introduced an edge-like environment through densely forested areas that provided habitat for birds and small mammals preferring semi-open conditions.

The Atchafalaya basin of Louisiana contains large tracts of cypress-tupelo swamp that are crisscrossed with pipeline canals. Pullen (1981), based on long professional experience with the basin, noted that pipeline canals through these swamps have created two common problems: 1) Continuous spoil banks along the canals interrupt water flow, causing areas "downstream" of the banks to be starved for water, while water stagnates and goes anoxic over large areas "upstream" of the banks. 2) Canals that lead from a stream channel to the middle of a swamp area may carry large quantities of water and sediment from the stream during floods, burying the swamp under sediment.

A final cause of concern is the pumping of water from pipeline ditches during construction. Such water may be highly acidic, anoxic, and high in nitrates; its uncontrolled release to nearby surface waters may have several undesirable effects.

Most of these impacts can be fairly easily mitigated by appropriate construction and restoration methods, such as the use of temporary plugs, complete and proper backfilling of the pipeline ditch, and care in choosing whether and how to drain ditch water during construction. As in coastal wetlands, the excavated spoil may not be sufficient to completely refill the trench, and additional material may have to be brought in from elsewhere.

These measures cannot reduce the habitat lost during wetland construction, and routing will largely determine the magnitude of this impact. Because of the extent of these wetland types in the coastal plain, it is not practical or necessary that pipeline routes avoid them at all costs, but there are several routing criteria that could be applied to minimize the severity of loss. These are:

1) Existing rights-of-way should be shared or parallelled whenever possible.

2) Previously disturbed or low quality tracts are preferable for pipeline routes. The higher quality stands of swamp and bottomland forests and outstanding tracts of pocosins, particularly those that are still in an undisturbed, natural state, should be avoided.

3) Cypress-gum and hardwood swamps are typically long, linear features along winding stream courses. Where such forests must be crossed, the crossing should be at a narrow point and approximately perpendicular to the long axis of the forest tract; the route should not pass lengthwise through these forests for any substantial distance.

7.10 UPLAND ECOSYSTEMS

Cooper et al. (1975) describe three natural upland vegetation types in eastern North Carolina, exclusive of the coastal strand:

1) Pine flatwoods, or savanna. This community forms both on gently sloping sand ridges and on extensive, poorly drained flatlands in the southeastern part of the state. It is dominated by scattered pines and a normally continuous cover of grasses, thought to be maintained by periodic fires. The dominant tree species are pond pine and longleaf pine; common shrubs include gallberry, wax myrtle and sweet bay, while wire grass, other grasses and a rich wildflower community make up the herbaceous layer.

2) Longleaf pine-turkey oak-wire grass community. This type is typically

found on deep, well-drained, coarse sands of the coastal plain, in drier sites than the pine flatwoods. The community is most common in the sand hills but also occurs on the deep sands of old dunes and terraces associated with ancient inland shorelines, mostly in the southeastern corner of the state. The vegetation often has a distinctive appearance, usually consisting of an open layer of scattered longleaf pines and a lower layer of scrub oaks, primarily turkey oak, bluejack oak, blackjack oak and scrubby post oak. Dwarf huckleberry and wire grass are the dominant ground covers.

3) Oak-hickory forest. This type was once found on the well-drained (but not droughty) soils of the northern coastal plain, but because these areas possessed the most desirable agricultural soils, little of this community remains in a natural state. Oaks (including white, southern red, water, willow and others), hickories, sweet gum, tulip poplar, beech, black gum, red maple and pines were most common.

Most of the impacts of pipeline construction on these areas will result from clearing of the right-of-way and maintenance of a grass/shrub community within it for the life of the project. There will, of course, be a temporary loss of most vegetation and fauna within the right-of-way as a result of construction activities. The extent to which this disturbance will have a long-term impact will depend primarily on 1) the speed with which revegetation occurs, and 2) the degree to which trees were important structural and functional components of the original ecosystem.

Revegetation is essential if a productive biotic community is to be re-established. In areas that do not revegetate, there will be a loss both of primary productivity and of most wildlife use of the habitat. The area will also be prone to accelerated erosion, which in turn will make revegetation even more difficult as well as subjecting adjacent land areas and streams to large inputs of sediment.

Since trees are not permitted to grow on the permanent right-of-way, the greater the role that trees played in the original ecosystem, the greater will be the change in the natural community as a result of pipeline construction. Where the vegetation is relatively open, with scattered trees, the impact of a permanent 40-foot strip of herbaceous and shrubby vegetation is apt to be much less than in a densely forested area. That is not to say that the impact will be adverse -- it is possible that an herbaceous corridor through a forest will increase habitat diversity and wildlife populations -- but it will represent a greater change from the original community structure. In disturbed areas outside of the permanent right-of-way, forested communities also are apt to be slower to recover to preconstruction conditions than areas with a predominantly herbaceous cover.

Where the forest is dense and the canopy near continuous, sudden clearing of a swath of land will increase the exposure of adjacent trees, possibly leading to increased windthrow of shallow-rooted species, increased breakage of limbs and tops, and sunscald (FPC, 1977). The result will be to weaken these trees and increase their susceptibility to insects and disease. In more open communities where the trees are scattered, such impacts will be rare.

Other potential impacts of pipeline construction in upland ecosystems have been discussed at greater length elsewhere in this report. Soil fertility may be reduced as a result of compaction, erosion, and the mixing of

subsoil with topsoil, which in turn could slow right-of-way revegetation and alter species composition. The prevalence of relatively level, sandy soils in the coastal plain uplands minimizes these concerns. The wildlife populations of these communities will also be affected by construction activities, long-term habitat changes, and right-of-way maintenance procedures. These were discussed in the section on wildlife and waterfowl.

In general, there will be relatively little impact from pipeline activities on natural upland communities in eastern North Carolina. Densely forested areas should be avoided when possible, unless rights-of-way can be demonstrated to have strong positive impacts. Care needs to be paid to revegetation, and prompt measures should be taken (fertilizers, mulch, seeding) where revegetation appears to be failing.

7.11 SOILS AND DRAINAGE

There are four major potential impacts of pipeline construction on soil resources: soil compaction, soil erosion, the contamination of topsoil with excavated subsoil, and disruption of drainage lines.

Contamination of topsoil with subsoil. In most soils, the top several inches are relatively rich in organic matter, nutrients and soil biota. This topsoil provides a more fertile growing medium than the relatively inorganic and nutrient-poor subsoil. This is especially true in agricultural areas, where often through years of cultivation farmers have improved the upper soil layers by adding nutrients and organic matter, and by balancing pH.

Pipeline construction can result in the mixing of subsoil with topsoil in several ways: through the initial grading of the right-of-way, through the excavation and backfilling of the pipeline trench, and through the spreading of excess subsoil over the right-of-way during cleanup. In general, the mixing of subsoil with topsoil will have an adverse impact on soil fertility and soil structure. The severity of the impact will depend on the nature of the subsoil. Highly alkaline or acid subsoils may inhibit plant growth, heavy clays may reduce infiltration, and sands and gravels may increase permeability to the point of droughtiness (USDOI, 1976). Under certain circumstances, the mixing of subsoil with topsoil could improve soil fertility, as where beds of sand or marl underlie excessively clayey or acid soils, respectively.

In eastern North Carolina, soils tend to be acid and low in fertility. They vary in texture from the sandy soils of barrier islands and sand hills to the loamy and clayey soils of wet lowlands. For the most part, the coastal plain is an area of low relief, so that grading of the right-of-way will only occasionally be necessary.

Where subsoil and topsoil are mixed in this area, a decline in soil fertility can be expected that under natural processes could take ten to twenty years to fully make up. Without additional treatment, revegetation may occur slowly, and crop yields the first year after construction could be as much as 50% lower (Canterberry, 1981).

To minimize these losses, several measures can be taken, the applicability and design of which will vary with specific soil conditions:

1) Proper applications of lime and fertilizer could restore much of the lost productivity almost immediately (Hayhurst, 1981).

2) The trench can be double-ditched, which involves removing, stockpiling and replacing the trench's topsoil and subsoil separately. In the opinion of USDOI (1976), double-ditching "is considered the most vital single factor in restoring vegetation and reducing soil erosion, water and air pollution, and losses of productive potential." In the past, double-ditching has been done where landowners (particularly farmers) have requested it, but it has not been standard procedure in this country, though it apparently is in Britain (Moffatt, 1975). The effectiveness of this technique will depend on the care with which it is practiced; stockpiled topsoil needs to be protected from water and wind erosion, and the depth of proper topsoil excavation will vary with soil conditions.

3) Excess subsoil left after the trench has been backfilled can be trucked away and used as fill rather than being spread out over the right-of-way (USDOI, 1976).

Soil Compaction. The use of heavy equipment on the right-of-way will compact the soil, reducing aeration, infiltration capacity, and permeability, thereby reducing plant growth and increasing surface runoff and erosion. Compaction tends to be more severe on wet soils, which are common in the lower coastal plain where the water table remains within a few feet of the surface year-round. Even in the better-drained upper coastal plain and Piedmont, however, saturated soils are common in the late winter and early spring. Compaction also tends to be more severe in clayey soils than sandy ones; the former occur in parts of the coastal lowlands, but are more prevalent in the Piedmont.

In general, soil compaction as a result of pipeline construction will not be a major problem, but it can be significant locally. The extent and effects of compaction can be reduced in several ways. Seasonally saturated soils should be avoided in season, and balloon tires or wooden mats can be used to distribute weight over a larger area. The soil can also be cultivated following construction, but this alone cannot restore compacted soils; disking and harrowing are only effective in the upper few inches of the soil, and while subsoiling can break up lower compaction and hardpans, it does so only at intervals and incompletely (Canterberry, 1981).

Soil erosion. The removal of vegetation and the churning and breaking up of soil particles by construction equipment will expose soils in the right-of-way to accelerated erosion by water. The amount of erosion will depend on several factors, including slope, soil erodibility, time needed for revegetation, and amount and intensity of rainfall. Problem areas often include stream banks and the pipeline ditch itself. Stream banks frequently are steep and may be exposed periodically to erosive floods; moreover, erosion here contributes directly to stream sedimentation, without the benefit of any buffer. Pipeline trenches may be foci of water erosion for several reasons: the looseness of the backfill, the tendency of the trench to act as a drain, and the concentration of runoff by the crown left above the trench to compensate for natural settlement of the backfill (or conversely, by the depression left where settlement exceeds the excess materials provided). Wind erosion of exposed soil in the right-of-way may also occur, but in the eastern United States tends to be significant only locally.

The effects of accelerated erosion are two-fold: a decline in the fertility of the soil as the more fertile topsoil is carried away, and sedimentation of water courses receiving the eroded material.

Topographic relief in North Carolina increases as one moves westward from the coast, and the erosion potential of the state's soils generally follow this trend. One would expect relatively minor erosion problems in the coastal counties as a result of pipeline construction (with local exceptions), with increasingly greater problems as one moves into the middle and upper coastal plain and then into the Piedmont.

There are a variety of measures available and commonly used for controlling erosion on pipeline rights-of-way. By far the most important is the rapid reestablishment of a vegetative cover. Revegetation can be accomplished naturally, by artificial seeding, or by plantings, and in most cases can be substantially accelerated with fertilizers. The appropriate species and methods for revegetation will vary from area to area, and the decision should involve a number of considerations, including ecological compatibility and aesthetic value.

Structural measures available include check dams and cross ditches built across the right-of-way to break up water flow, gravel-filled trenches ("French drains") on the uphill side of cross-slope pipeline trenches that collect and divert runoff before it enters the pipe trench, and sandbag ditch breakers placed at intervals in the pipe trench to prevent erosion of the backfill (USDOI, 1976). Streambanks may require additional measures such as retaining walls, riprap and chemical stabilizers. Special measures may also be needed at temporary or permanent drainage outlets and at the outfall for hydrostatic test water to prevent erosion and scour. U.S. Department of Agriculture/Soil Conservation Service (1973) discusses a number of control measures generally found useful on construction sites in North Carolina.

The choice of which control measures are employed will be influenced by two agencies with jurisdiction in this area. As a result of FERC's general environmental review authority for interstate gas lines, that agency has established guidelines for pipeline construction and maintenance at 18 C.F.R. §2.69; these include a number of general admonitions regarding appropriate erosion control. In addition, the North Carolina Sedimentation Pollution Control Act of 1973 (G.S. §113A-54), discussed in Chapter IV, requires approval of erosion control plans by the Division of Land Resources for large ground-disturbing activities.

Disruption of drainage lines. Drainage is a key factor in determining the types of plant communities a soil will support. One only need examine the differences between wetland and upland ecosystems to appreciate the role of drainage in natural systems. For many farmers and some foresters, drainage plays a crucial role in determining the size of harvests.

Over large areas of eastern North Carolina the water table occurs within a few feet of the surface, and artificial drainage has been used extensively in agriculture and forestry to improve soil conditions for crop growth. One recent study (Doucette and Phillips, 1978) estimated that, in the 17 coastal counties responding to their survey, 9.2% of the land area (513,000 acres) was extensively drained for farming with subsurface tile systems combined with

surface drainage methods; an additional 23.7% (1,321,000 acres) was partially drained for farming and forestry with drainage ditches and surface drainage measures. Subsurface tile systems are more common west of the Suffolk Scarp and reach their maximum use in counties such as Martin, Pitt and Duplin in the central coastal plain. East of the Suffolk Scarp, most drainage is by open ditches.

Pipelines must be laid underneath existing drainage systems so as not to interrupt water flow. Both open ditches and tile lines are commonly built 4 to 8 feet beneath ground level in eastern North Carolina (Doucette and Phillips, 1978), requiring pipelines to be installed as much as ten feet below the surface. Such deep burial will involve a correspondingly greater trench top width and larger volumes of excavated material.

Pipeline construction may disrupt existing drainage in several ways. Small natural channels, open ditches, and tile lines may be temporarily blocked during construction. Improper tile drain restoration often results from fast work, loss of marker posts, and use of cracked tiles, and ground settlement in the trench may displace properly restored tile drains. Tile drains or open ditches may become clogged with sediment as a result of construction and improper restoration. Loosely backfilled pipeline trenches may themselves act as drainage channels, transferring water from one basin to another, lowering water tables, and perhaps overloading tile systems at low points along the trench (Moffatt, 1975; USDOI, 1976).

Clogged drainage lines will result in excess soil moisture in the drainage area during certain times of the year. Depending on the time and duration of these periods, crop yields may be sharply reduced and farming operations made very difficult. Lowering of the water table by the trench itself is of greater concern in natural wetland ecosystems where drainage can be sufficient to convert the wetland to dry land.

A number of steps can be taken to minimize disruption of drainage lines. The trench should be open for as short a time as possible, particularly in the spring when proper drainage is critical. Tile lines should be carefully restored (see Moffatt, 1975, for guidelines). Small wetlands, particularly those with perched water tables, should be avoided if possible, or measures taken to prevent accidental drainage.

<u>Sources</u>. The major sources of soils information in eastern North Carolina are the county soil surveys being conducted and published by the Soil Conservation Service. The status of these surveys for the twenty coastal counties is given in Table 7-6. For counties where surveys are not yet available, soils information for selected areas may be obtained at the county Soil Conservation Service field offices.

7.12 AIR QUALITY

There are three sources of air pollutants generated during pipeline construction: 1) emissions of construction vehicles and other equipment; 2) fugitive dust from land disturbance on the right-of-way and access roads; and 3) pollutants from open burning of forest debris accumulated during right-of-way clearing. In addition, pollutants are generated by various temporary and permanent facilities associated with the pipeline, including pipe coating

Table 7-6. Status of SCS County Soil Surveys in coastal North Carolina, October 1981.

County	Modern Published Soil Survey	Modern Soil Survey with Field Mapping Completed, to be Published	Modern Soil Survey Being Conducted with Date for Completion Set	No Modern Soil Survey Being Conducted, Soil Mapping by Request
Beaufort			X	
Bertie			X	
Brunswick			X	
Camden				X
Carteret			X	
Chowan		X		
Craven			X	
Curituck		X		
Dare				X
Gates				X
Hertford			X	
Hyde				X
New Hanover	X			
Onslow			X	
Pamlico			X	
Pasquotank	X			
Pender			X(part)	X(part)
Perquimans		X		
Tyrrell			X	
Washington		X		
Outer Banks	X			

yards, pump and compressor stations, and gas separation plants. The air quality impacts of these facilities are discussed in the section on ancillary facilities (Section 9.2), and only the construction of the pipeline itself will be discussed here.

Carbon monoxide, nitrogen oxides, hydrocarbons, sulfur oxides, particulates and dust are the major pollutants generated during pipeline construction. The impact of these emissions on ambient air quality will depend of course on the rate of emission, but also on local topography and meteorological conditions. Whether these emissions will adversely affect human health and welfare and other biological systems will also depend on pre-construction ambient levels.

When present in sufficient concentrations, these pollutants may cause eye irritation and respiratory difficulty in humans. Some pollutants are known to impair the functions of the central nervous system, and others are suspected carcinogens. They are the cause of structural deterioration in buildings and other objects, and significantly increase our annual cleaning bills. They have also been shown to bleach plant pigments, thereby reducing photosynthesis and plant growth (Golden et al., 1980).

Construction equipment. Emissions of construction equipment along the right-of-way will depend on the type of equipment used and the extent of its use. The U.S. Environmental Protection Agency has compiled average emission rates for several categories of heavy-duty, gasoline- and diesel-powered construction equipment (USEPA, 1977). From these factors and from average equipment lists for pipeline spreads, Golden et al. (1980) calculated

estimated daily vehicular emissions from a typical big-inch pipeline spread. These are shown in Table 7-7, along with the anticipated emissions of oil pipeline spreads that were to have constructed Sohio's California to Texas pipeline, as reported in NERBC (1976).

Table 7-7. Estimated Daily Vehicular Emissions Generated by Big-Inch Pipeline Spreads.

Pollutant	Golden et al. (1980)	NERBC (1976)
Hydrocarbons	438 lbs/day	214 lbs./day
Nitrogen Oxides	1868	3420
Sulfur Dioxide	131	226
Particulates	84	160
Carbon Monoxide		653
Fugitive Dust	1264	

Fugitive dust. Fine soil particles pulverized by construction equipment may be entrained by turbulent air currents or high ground wind speeds and carried anywhere from a few feet to several miles. This so-called fugitive dust can have a substantial temporary impact on local air quality. The amount of dust generated will vary substantially from day to day and place to place, depending on the level of construction activity, the specific operations being conducted, the characteristics of the soil, and prevailing weather conditions. Equipment traffic over the right-of-way and access roads is apt to be the largest source of dust emissions (USEPA, 1977).

In general, the quantity of dust generated is proportional to the area being worked, the level of construction activity, and the silt and clay content of the soil, and is inversely proportional to the square of the soil moisture content (USEPA, 1977). Taking EPA's approximate dust emission factor for a medium level of construction activity on soils with a moderate silt/clay content (30%) and adapting it to average soil moisture conditions in eastern North Carolina yields a rough estimate of .26 tons of fugitive dust emissions per acre of construction per month of activity. For coastal plain soils with a higher silt/clay content, this figure will be proportionally higher. Assuming that construction activity at any one location may take from 5 days to 4 weeks, and that the width of the actively used right-of-way may range from 50 to 100 ft., an approximate range for dust emissions for 30% silt/clay soils is 0.3 to 2.9 tons per pipeline mile.

There are no measures for controlling fugitive dust that are completely satisfactory. Watering is the most common control method and has been shown to reduce fugitive dust emissions by up to 50%, if done twice daily with complete coverage. Chemical stabilizers are also available, but these are generally applied only after construction is completed to help stabilize the soil until revegetation occurs. Stabilizers also may have adverse impacts on plant and animal life, or may contaminate the treated material (USEPA, 1977).

Open burning. Pollution during construction will also occur if open burning is used to eliminate forest residues accumulated during right-of-way clearing. A study reported in USEPA (1977) found that unspecified forest residues generated 17 lbs. of particulates per ton of fuel burned, 140 lbs./ton for carbon monoxide, 24 lbs./ton for hydrocarbons, and 4 lbs./ton for nitrogen

oxides. The character and amount of emissions will be influenced by several variables, including wind, ambient temperature, composition and moisture content of the debris, and compactness of the pile.

The effect of pollutants generated by these three sources during pipeline construction will be a temporary, and in most cases minor, deterioration in air quality near the construction site. The implications for pipeline siting are negligible. Air quality in eastern North Carolina is generally quite good; the entire area is listed by the EPA as better than national standards or unclassifiable for all five pollutants examined (particulates, sulfur dioxide, ozone, carbon monoxide, and nitrogen dioxide). Atmospheric temperature inversions, which can cause normally safe emission levels to accumulate to dangerously high concentrations, do occur in North Carolina, most commonly in August or September. However, inversions of sufficient magnitude to be of concern are relatively rare in the coastal plain (Kopec and Clay, 1975; Sewell, 1982).

The N.C. Division of Environmental Management (DEM) can exert some control over the air pollutants generated by construction activities. There are no regulations governing equipment or fugitive dust emissions during pipeline construction, but DEM normally seeks the cooperation of the contractor in minimizing emissions from these sources (Sewell, 1982). There are state regulations governing open burning (15 N.C.A.C. 2D .0520), and these require a permit to burn from DEM. Several types of burning are excepted, including burning for land clearing and right-of-way maintenance, either where no other practicable or feasible methods of disposal are available, or in rural areas where conditions regarding weather, time, location, and content of debris must be met. Where permits are needed, similar conditions are attached. The state also has the authority to prohibit all open burning, and to require other steps to reduce emissions, when stagnating air creates an air pollution emergency (15 N.C.A.C. 2D .0300).

7.13 NOISE

Increases in noise over ambient levels will occur during pipeline construction and operation. High noise levels have been shown to have several adverse effects on humans and animals. Masking and interference with speech communication are the most common. Other effects may include permanent or temporary loss of hearing, a shift in hearing threshold, interference with sleep, task interference, annoyance, and physiological stress. Little is known about the effects of noise on wildlife; it is presumed that auditory impairment in animals is similar to that in humans. Wildlife behavioral modifications in response to increased noise levels, such as relocation, have not been documented. (Central Inst. for Deaf, 1971; Weston, 1978)

The impact of a new facility or operation on ambient noise levels will be determined by several factors (Weston, 1978):

1) Ambient noise levels at the site prior to construction or operation. If a new source is louder than its surroundings, of course, noise levels near the source will increase. If the source is roughly equal to its surroundings, noise levels increase only minimally (about 3 dB at 80 dB), while if the source is less than its surroundings, there will be no change in noise level. Impacts in rural areas will generally be greater than in urban surroundings.

2) Physical characteristics of the area. The presence and design of

buildings, occurrence of vegetation and other barriers, and the local topography all influence the attenuation of sound.

3) Distance of listener from source. With every doubling of distance between noise source and listener, noise level drops approximately 6 dB.

4) Duration of the sound-generating operation.

The Federal Noise Control Act of 1972 (42 U.S.C. §§4901-4918) assigned primary responsibility to state and local governments for controlling the use of noise sources and the levels of noise permitted in the environment. Federal responsibilities, assigned to EPA, include noise emission control for mobile sources (regulations have been issued for portable air compressors, medium and heavy trucks, and garbage trucks) and the drafting of suggested guidelines on the levels of environmental noise "requisite to protect the public health and welfare." EPA published these guidelines in 1974, recommending that a 24-hour average noise level (weighted towards night-time to reflect lower tolerance of noise at night) of 55 dB(A) or less would be sufficient to prevent outdoor activity interference and annoyance for the vast majority of people (USEPA, 1974). Noise levels in the workplace are regulated under the Federal Occupational Safety and Health Act of 1970 (OSHA; 29 U.S.C. §§651-678, regulations at 29 C.F.R. §1910.95), and these same standards have been adopted by North Carolina for the state program.

Pipeline construction will have a temporary, adverse impact on noise quality. The noise levels generated and their resulting impact will vary with the specific equipment involved. Table 7-8 lists typical noise levels for different kinds of equipment used in pipeline construction (along with noise levels of some common activities for comparative purposes) and Table 7-9 lists noise levels for different pipeline construction activities. In general, typical noise levels attributable to a construction spread are about 70dB(A) at 250 ft. from the pipeline and 60 dB(A) at 2500 ft. (FERC and USDOI/BLM, 1981). Duration of the noise, however, is generally short.

In addition to the construction site, road noise will increase along the routes used to deliver equipment, men and materials to the site. The major contributor will be pipe hauling trucks. Estimates for the number of trips from pipe storage yards that would be required during construction of the North Border pipeline ranged from 17-33/day (USDOI, 1976), and similar frequencies can be expected in North Carolina.

Once the pipeline is operational, noise impacts will be restricted to ancillary facilities and occasional maintenance and repair activities along the line, such as airplane overflights and right-of-way mowing. The most severe of these from a noise standpoint are gas pipeline blowdowns, which occur at a compressor station or along the pipeline when gas is vented either as a maintenance check or during an emergency. Blowdowns may take up to 45 minutes for the pipeline and 5 minutes at a compressor station; noise levels may reach 140 dB(A) and may be heard for 15 miles, though levels can be reduced substantially with silencers (USDOI, 1976; NERBC, 1976).

Several measures are available to reduce noise impacts:

1) Noise levels can be significantly reduced by equipping all on-site engine-powered equipment with mufflers. Muffler performance standards should be specified, as the quality and effectiveness of mufflers vary widely (USDOI, 1976).

Table 7-8. Typical Noise Levels Generated by Pipeline Construction Equipment.

Equipment	dB(A) at 50 Feet
Side Boom	78-92
Backhoe	80-92
Bulldozer	82-95
Ditching Machine	80-90
Motor Crane	78-87
Dragline	80-90
Backfiller	82-95
Welding Rig	72-82
Air Compressor	85-91
Jack Hammer	88-98
Trucks (Heavy Duty)	82-92
Pickup Trucks	70-85
Automobile	65-76
Pile Driver	95-105
Scraper Grader	80-94
Generator	71-82

Source: FERC and USDOI/BLM, 1981.

Table 7-9. Typical Noise Levels Generated by Pipeline Construction Activities.

Activity	Maximum dB(A)	Mean dB(A)
Clearing	86	75
Grading	84	78
Trenching	92	88
Blasting	121 for 65 milliseconds	120
Stringing	87	80
Welding	87	77
Pipe Coating	91	84
Lowering-in	86	84
Backfill and Cleanup	89	87

Source: TAPCO Project: Supplemental Evnironmental Report, p. 3-10, as cited in NERBC, 1976.

2) Annoyance from construction noise is greatest in the evening and nighttime hours. In residential areas, construction activities should be limited to 7 a.m. to 7 p.m.

3) Certain facilities, such as schools, hospitals, and nursing homes require special consideration in anticipating noise impacts, and appropriate mitigation measures should be worked out for construction in their vicinity.

4) Road noise impacts from pipe-hauling trucks can be minimized by careful planning of pipe yard locations and hauling routes.

5) Blowdowns, blasting, and other especially noisy activities should be scheduled for the least disruptive times of day, if possible.

VIII. RESOURCE USES

8.1 COMMERCIAL FISHERIES

Over 75 species contributed to commercial fishery landings in North Carolina in 1981. The total dockside value of this catch was $57.5 million, down from a record $68.8 million in 1980 (Table 8-1). This catch was landed by over 4000 full-time, registered commercial fishing vessels, primarily at the major fishing ports of Wanchese, Beaufort/Morehead City, Southport, Pamlico, Hobucken, Belhaven, Oriental, Atlantic, Wrightsville Beach and Carolina Beach. Table 8-2 breaks down the preliminary landings for 1980 by water body; in terms of the harvest value of inshore waters, the list is led by Pamlico, Core and Bogue Sounds and the estuaries of several coastal plain rivers: the Pamlico, Neuse, North, Newport, New, and Cape Fear.

Research and management responsibilities for these fisheries are divided primarily among three agencies. The North Carolina Marine Fisheries Commission (and its staff, the Division of Marine Fisheries) establishes and enforces regulations on gear, seasons, and areas within state waters. The Division also conducts research on fishery stocks and gear, is engaged in an aggressive shellfish rehabilitation program, and has constructed a number of artificial reefs along the coast for the benefit of sport fishermen.

The National Marine Fisheries Service (NMFS) within the U.S. Department of Commerce is the primary federal fishery management agency responsible for establishing regulations and conducting research. A laboratory of the NMFS Southeast Fisheries Center is located in Beaufort.

Finally, the South Atlantic Fisheries Management Council is one of eight Regional Councils created by the Federal Fishery Conservation and Management Act of 1976 (16 U.S.C. §§1802-1882) to recommend measures for managing fish stocks within the United States' 200-mile fisheries jurisdiction. The major functions of the council are to prepare fishery management plans for stocks within the 200-mile zone and to recommend specific regulations designed to produce the annual "optimum yield" from these stocks. To date, only one plan, for spiny lobster, has been approved and the recommended regulations promulgated; other plans in various stages of preparation are for coastal pelagics (mackerel), billfish, swordfish, the snapper-grouper complex, coral, calico scallops, and shrimp. Rieser and Spiller (1979) have argued that such fishery management plans, by identifying critical fishery resource areas and sensitive periods of the year, are also useful for planning other activities in offshore waters (particularly oil and gas development) to minimize adverse effects on fishery stocks.

The potential impacts of pipeline operations on commerical fisheries are of two major types: impacts on fishery stocks, and impacts on fishing operations. The major North Carolina commerical fisheries that may show some sensitivity to pipeline operations are described in Table 8-3. Marine pelagic species, such as billfish and mackerel, are not included, as the impact of pipeline construction and operation on these fisheries will be almost nonexistent, barring a major oil spill.

Table 8-1. Preliminary North Carolina landings by species, 1980 and 1981. (Source: N.C. Tar Heel Coast, 17(2):4, March, 1982)

	1980		1981	
Fish	Pounds	Dollars	Pounds	Dollars
Alewives	6,218,523	444,327	4,753,723	316,850
Amberjacks	6,764	1,531	14,737	3,490
Anglerfish	623,409	218,598	234,539	96,500
Bluefish	5,443,558	760,630	6,610,459	1,242,677
Bonito	17,286	3,463	3,939	848
Butterfishes	148,617	41,971	281,294	108,161
Cobia	5,128	1,301	5,260	1,515
Carp	83,013	2,559	85,737	3,207
Catfishes and Bullheads	1,625,739	368,106	1,908,521	495,789
Cod	665	133	751	188
Croaker	21,146,798	5,213,755	11,205,342	3,944,643
Dolphinfishes	23,887	11,886	5,939	4,460
Drum, Black	75,375	8,709	91,916	6,038
Drum, Red	243,223	47,133	93,420	18,817
Eel, Common	960,196	1,038,575	436,007	256,433
Flounder, Blackback	19,608	3,851	4,604	2,839
Founders, Fluke, Unclassified	16,881,890	7,888,252	9,776,248	6,198,186
Flounder, Grey Sole	10,861	1,608	10,666	3,330
Flounder, Yellowtail	10,180	1,240	3,722	1,285
Gizzard Shad	1,312,093	39,372	270,400	5,471
Groupers	664,354	537,458	882,696	824,392
Grunts	57,241	28,478	77,868	16,802
Harvestfish	275,300	55,446	149,685	26,629
Herring, Thread	5,467,870	254,390	924,600	28,322
Hickory Shad	91,501	12,680	81,312	11,831
King Mackerel	768,946	646,543	736,073	648,544
King Whiting	342,605	110,436	254,651	89,396
Lingcod	13,198	1,943	274,252	51,378
Mackerel	1,874	203	145,358	23,094
Marlins	48	20		-
Menhaden	196,920,370	7,139,327	309,414,710	10,038,759
Mullet	2,215,532	360,145	1,293,902	259,094
Pigfish	100,091	12,251	53,848	10,279
Pinfish	8,410	822	777	80
Pompano	10,104	4,583	9,723	6,237
Scups or Porgies	1,751,763	865,848	2,178,151	1,172,247
Sea Basses, Unclassified	1,530,986	931,324	1,197,431	910,076
Sea Trout, Grey	20,343,952	3,783,923	16,893,546	5,305,036
Sea Trout, Spotted	171,334	75,216	113,304	59,371
Shad	199,206	88,112	351,500	189,793
Sharks, Dogfish	2,866	463	4,506	671
Sharks	20,891	2,673	96,434	46,810
Sheepshead	29,800	3,389	9,782	1,386
Snappers	422,374	727,478	512,378	938,864
Spadefish	295	207	13,860	2,460
Spanish Mackerel	75,306	29,898	51,639	22,004
Spot	7,100,053	1,493,437	3,511,574	823,728
Striped Bass, Unclassified	472,503	435,479	417,324	451,824
Sturgeons	30,012	11,163	31,482	12,804
Swellfishes	30,985	12,493	22,838	6,876
Swordfish	316,576	455,243	251,428	562,317
Tautog	477	103	-	-
Tilefish	24,708	8,907	55,648	26,391
Triggerfishes	29,573	6,830	40,876	11,099
Tripletail	288	37	-	-
Tunas	98,738	21,311	32,195	23,197
Wahoo	2,327	1,515	1,030	922
White Perch	104,803	26,954	395,312	120,827
Whiting	670,166	82,897	3,149,035	545,805
Yellow Perch	4,658	883	7,611	1,791
Unclassified for Industrial	12,817,134	398,246	9,117,328	298,465
Total Fish	308,046,031	34,725,754	388,522,891	36,280,328
Shellfish				
Crab, Blue, Hard	34,322,937	5,975,221	37,927,573	8,172,428
Crab, Blue, Soft	87,482	132,448	77,748	100,860
Crab, Horseshoe	29,072	5,726	5,895	1,630
Lobster, American	963	2,169	91	341
Shrimps (Heads On)	9,823,490	17,184,994	2,557,426	5,295,209
Clams, Hard (Meats)	1,541,719	5,554,047	1,458,196	5,386,803
Conchs (Meats)	56,933	28,836	29,674	16,522
Octopus	8,139	8,139	834	882
Oyster, Private, Spring (Meats)	54,895	67,903	2,966	3,923
Oyster, Public, Spring (Meats)	274,090	350,232	189,219	247,565
Oyster, Private, Fall (Meats)	4,972	8,165	1,363	2,262
Oyster, Public, Fall (Meats)	389,142	561,658	356,954	476,543
Scallop, Bay (Meats)	327,780	1,107,072	189,441	655,725
Scallop, Calico (Meats)	-	-	244,324	307,215
Scallop, Sea (Meats)	861,012	2,979,338	124,553	477,911
Squids	302,264	75,050	278,290	91,652
Turtles, Snapper	61,885	16,748	8,445	2,211
Total Shellfish	48,146,775	34,057,756	43,452,992	21,239,682
Grand Total	356,192,806	68,783,510	432,005,883	57,520,010

Table 8-2. 1980 Preliminary North Carolina landings by water.

WATER	POUNDS	VALUE($)
Edible Finfish and Shellfish		
Albemarle Sound	3,203,695	829,307
Bogue Sound	1,325,357	1,693,882
Cape Fear River	1,330,765	950,801
Chowan River	7,852,469	638,199
Core Sound	10,963,145	6,203,087
Masonboro Sound	487,050	586,473
Neuse River	8,142,524	2,296,982
New River	1,101,551	1,370,995
Newport River	1,511,197	1,326,364
Pamlico River	4,192,465	1,158,107
Pamlico Sound	48,133,981	16,525,121
Topsail Sound	508,481	509,328
North River (Carteret Co.)	1,158,570	939,995
Inland Waterway	699,579	935,856
Other Inshore	5,142,940	2,364,860
Total Inshore	95,753,769	38,329,357
Atlantic Ocean	58,050,797	23,060,436
Industrial Finfish		
Menhaden landings	196,920,370	7,139,327
Thread Herring landings	5,467,870	254,390
State Total	356,192,806	68,783,510

Source: Division of Marine Fisheries, N.C. Dept. of Natural Resources and Community Development.

8.1.1 Impacts on Fishery Stocks

Most of the adverse impacts of pipelines on fish stocks will result from bottom disturbances, habitat alteration, turbidity and other effects associated with pipeline burial. These will be restricted to shallow inshore areas and, where the pipeline is buried offshore, in the lower few feet of the water column. Where the pipeline is not buried, the net effect on fish stocks may be positive, by virtue of the additional firm substrate and relief provided by the pipeline.

Many of the impacts of pipelaying on shellfish and finfish have been discussed in other sections of this report (see Sections 7.1, 7.2, 7.4 and 7.7) and will be reviewed here only briefly. Mollusks, particularly immobile oysters, are susceptible to several effects of pipelaying: 1) physical destruction during dredging; 2) burial from spoil deposition; 3) sedimentation

Table 8-3. Major North Carolina commercial fish species and fisheries sensitive to pipeline activities.

SHRIMP

Brown shrimp
(Penaeus aztecus)
White shrimp
(P. fluviatiles)
Pink shrimp
(P. duorarum)

Biology/Distribution: Found throughout the state's estuarine waters from Pamlico Sound south, though their relative abundance varies according to habitat preferences. All three species possess similar life cycles. Spawning occurs offshore and the eggs hatch and larvae develop in the ocean. Postlarval stages enter the estuaries and migrate to shallow estuarine nursery areas, where development proceeds for 2-3 months before the young begin moving on ebb tides down the tributaries and towards the inlets and river mouths, back to the ocean. The seasonal timing of this pattern varies among species:

Species	enter estuaries (peak)	harvest (peak)
brown	March - May	July - August
white	June - July	Sept. - Nov.
pink	July - Sept.	late Sept. - Nov. and April - June

Fishery: Harvest is primarily by trawl, and secondarily by channel nets, from April through November. Most of the catch (about 80%) is taken from internal waters, and the rest within 3 miles of shore. Major shrimping areas are Pamlico Sound (about 50% of catch), Core and Bogue Sounds, and the estuaries of the North, Newport, White Oak, New and Cape Fear Rivers. Over the past dozen years, browns have accounted for roughly 2/3 of the catch, pinks for about 1/4, and whites less than 1/10.

CRABS

Blue crab
(Callinectes sapidus)

Biology/Distrubution: Found throughout the estuarine waters of the state, including the east half of Albemarle Sound. Blue crabs spawn near inlets in both the spring and fall; large concentrations occur at the inlets from Cape Lookout north (Barden, Drum, Ocracoke, Hatteras and Oregon). After several planktonic larval stages, young crabs migrate into the estuaries, concentrating in nursery areas and grass beds, and slowly spread throughout the estuaries and sounds as they grow older. Following mating, the males remain in brackish waters, while females migrate back to inlets to spawn.

Fishery: Most of the harvest (approx. 80%) is taken with pots, and the remainder by trawl. Major areas of commercial crabbing are Pamlico Sound, the Neuse and Pamlico Rivers, Core Sound, and their tributaries.

CLAMS

Hard Clam
(Mercenaria mercenaria)

Biology/Distribution: Found in estuarine waters from Core Sound south. Spawning occurs during the summer; following a short planktonic larval stage, the young undergo metamorphosis and burrow into the bottom.

Fishery: Two groups of harvesting methods are used: 1) Mechanical methods, principally by clam kicking (the use of propeller wash to dislodge clams from the bottom), but also with hydraulic escalator dredges, account for roughly 1/3 of the harvest during a strictly controlled season from Nov. to March; 2) Hand methods (tongs and rakes, used year-round) account for the remaining two thirds.

OYSTERS

Eastern oyster
(Crassostrea virginica)

Biology/Distribution: Found in estuaries on firm substrate from Pamlico Sound to the South Carolina border, in both deep and shallow water. Spawning occurs from May to September; after a variable planktonic period of approximately two weeks, larvae settle and undergo metamorphosis. The species may occur individually or in substantial reefs.

Fishery: In Pamlico Sound the harvest is taken primarily by power dredge; from Core Sound south, rakes and tongs are the principal methods.

SCALLOPS

Bay Scallop
(Argopecten irradians)
Calico scallop
(A. gibbus)
Sea scallop
(Placopecten magellanicus)

Biology/Distribution: Bay scallops occur moatly in Bogue Sound associated with aea grasses, and play out around New River to the south. The Calico scallop is a marine species, somewhat unpredictable in appearance; commercially valuable beds appear every 3-7 years east of Cape Lookout and south of Beaufort bar. Sea scallops are not harvested off North Carolina, and landings in the state are due to N.C. boats fishing mid-Atlantic stocks.

Fishery: Bay scallops in Bouge Sound are harvested from December to March, mostly with scallop drags (dredges without teeth) pulled through grass beds, and some by hand. Calico beds, when they appear, are usually fished out with dredges in a matter of weeks.

Table 8-3. (Continued)

SCIAENIDS AND FLOUNDER	
Croaker (*Micropogon undulatus*) Spot (*Leiostomus xanthurus*) Grey Trout or Weakfish (*Cynoscion regalis*) Summer Flounder (*Paralichthys dentatus*) Southern Flounder (*P. lethostigma*)	Biology/Distribution: These species all have similar life histories. Spawning occurs offshore during the winter, and larvae migrate across the estuaries to primary nursery areas, reaching peak abundance in spring. As they develop, juveniles move slowly down the tributaries and into the sounds, becoming vulnerable to the sound fishery by the end of the first year. The majority move out through the inlets in fall, though some overwinter in the sounds. Fishery: The fishery for these species traditionally has had two segments: 1) an inshore fishery from spring through fall, using pound nets, long haul seines, and by-catch from shrimp trawling; and 2) an offshore winter trawl fishery along the Outer Banks, from roughly Ocracoke north to the Virginia line, in up to 50-100 fathoms.
MENHADEN	
Menhaden (*Brevoortia tyrannus*)	Biology/Distribution: See Sciaenids and Flounder. Adults engage in extensive coastal migrations. Northward migration occurs in spring, with older and larger fish migrating the furthest. In autumn, large schools occur off North Carolina in October and November, finally disappearing in the vicinity of Cape Fear in December. Fishery: The fishery is tied to the adult migrations. From May through August, stocks migrating northward and summering in both inside and offshore waters are fished; from mid-October through November, the large schools moving south are fished between Cape Hatteras and Cape Fear. Virtually all are taken with purse seines.
ANADROMOUS FISH	
American shad (*Alosa sapidissima*) Hickory shad (*A. mediocris*) Alewife (*A. pseudoharengus*) Blueback herring (*A. aestivalis*) Striped bass (*Morone saxatilis*) Atlantic sturgeon (*Acipenser oxyrhynchus*)	Biology/Distribution: These species migrate through estuaries and up freshwater rivers to spawn; spawning runs occur from February to May. The young generally spend their first summer feeding in the river, then slowly move towards more saline portions of estuaries, migrating into the ocean after 1-2 years. Adults remain in the ocean for several years, migrating north and south, before returning to the streams of their birth to spawn. Fishery: These species are harvested with gill nets and pound nets during their spawning runs, and there exists heavy sport fishing pressure on some species as well. Major anadromous fishing areas are Albemarle Sound and the Pamlico, Pungo, Neuse, and Cape Fear Rivers.
REEF FISH	
Snappers (*Lutjanus* spp., *Rhomboplites aurorubens*) Groupers (*Epinephelus* spp., *Mycteroperca* spp. Porgies (*Pagrus pagrus*, *Calamus* spp.) Black Sea Bass (*Centropristis striata*)	Biology/Distribution: Found near rock outcrops, coral reefs, wrecks and similar bottoms, in some cases to depths of 800-900 ft. or more. These species are completely marine. Most have protacted spawning times; the eggs are pelagic and the larvae thought to be so, at least for a short time. Fishery: Snappers, groupers and porgies are taken with handlines mostly from rocks and other live bottoms well offshore. While some sea bass are also harvested in this fishery, most are taken closer to shore in the winter trawl fishery off the Outer Banks and in a fishery using handlines and traps in the Cape Fear, Cape Lookout and Cape Hatteras areas.

Sources: Whitehurst, 1973; Pendleton, 1976; USDOI/BLM, 1981c; Epperley, 1982; Holland, 1982; Munden and Marshall, 1982; Spitzbergen, 1982.

from both sediment suspended during dredging and redistributed spoil (particularly harmful to newly settled spat and young oysters); and 4) high turbidities, potentially harmful to both pelagic larvae and adults.

Juvenile crustaceans and the young of several groups of finfish (sciaenids, flounder, menhaden) concentrate in large numbers in limited areas, particularly primary and secondary nursery areas, wetlands and grass beds. Young are generally more sensitive to high turbidities and other environmental disturbances, and given this and their tendency to concentrate in restricted areas, these species are particularly sensitive to disturbances of these environments.

Adult crustaceans and finfish will avoid areas of construction activity for the most part, unless attracted by food organisms. The primary impact of pipelaying on adult stocks will be longer-term alterations of habitat that reduce food supplies, cover, and other important habitat characteristics. Such changes will be felt most intensely where the habitat disturbed is both productive and limited, such as grass beds (bay scallops, pink shrimp) and rock outcrops (reef fish).

Anadromous fish are particularly sensitive to two types of environmental change: instream activities during spawning runs that disorient or stress the fish, and alteration of the essential characteristics of their spawning beds (e.g., sediment grain distribution and water flow).

Since pipelaying's impact is restricted to inshore waters and the lower few feet of the water column offshore, marine pelagic species such as mackerel, billfish and tuna will experience no direct impact. Very minor indirect effects may occur as a result of changes in populations of food fishes.

A variety of measures are available to reduce the potential impact of pipelaying on these fisheries, and most of these have been discussed previously. These include rerouting, avoiding sensitive periods of the year, and restoring or replacing disturbed habitats. Another approach is direct compensation to fishermen. As part of North Sea oil and gas development, oil companies recognized that the laying of lines across valuable fishing grounds would cause an economic loss to the fishing industry and agreed to compensate fishermen accordingly. In May of 1975, for instance, Shell paid £25,000 to the Shetland Fishermen's Association for the disturbance associated with laying of the Brent oil line to Sullom Voe, and in July, British Petroleum paid the Association £45,000 to compensate for disturbance caused by construction of the Ninian line (Dames and Moore, 1981).

8.1.2 Impacts on Fishing Operations

There exist two potential sources of conflict between pipeline operations and fishing activities: interference of the pipelaying operation itself with fishing, and interference of the pipeline and associated debris with the use of fishing gear, particularly bottom trawl gear.

Pipelaying Interference with Fishing Activities. Interference between pipelaying operations and fishing activities will be temporary and in most cases minimal, depending on the location and time of year. It is standard

practice for the pipeline contractor to stake out the route for his sake and that of fishermen, and fishermen usually give wide berth to construction operations (Dunham, 1982).

The potential for conflict can be minimized by providing adequate notice to fishermen through Local Notices to Mariners, marine broadcasts, and other channels. An additional measure has been used in the North Atlantic, where stipulation No. 8 attached to Sale 42 leases requires oil company supervisors and vessel operators to complete a fisheries training program "to familiarize persons working on the project of the value of the commercial fishing industry and the methods of offshore fishing operations and the potential hazards, conflicts and impacts resulting from offshore oil and gas activities." The theory behind this stipulation is that vessel operators with a better understanding of fishing methods will better appreciate the limited maneuverability of fishing vessels when towing gear and will be less likely to accidentally cut gear. The opinion of one leader of the fishing community, however, is that the program has been only marginally effective and not worth the time and money involved (Lanjillo, 1982).

Other potential conflicts include competition for labor, port space, and facilities. These have been examined by Centaur Associates (1981).

Gear Hazards and Loss of Fishing Access. Several types of bottom fishing gear are used in North Carolina waters and offshore that could be damaged by seabed protuberances such as pipelines and associated debris. Most common are the bottom or otter trawls used for shrimp, flounder, sciaenids and other demersal finfish. Shrimp trawls are used extensively inshore and within three miles of the barrier beaches offshore; finfish trawls are used in the winter trawl fishery, primarily off the Outer Banks, for flounder, spot, croaker and others in depths to 50-100 fathoms (300-600 ft.) Dredges used for scallops, oysters, and clams are employed primarily in inshore waters, except for the occasional fishing of calico scallop beds off Cape Lookout. Handlines and pots are also common in North Carolina; lines are used regularly for harvesting reef fish from much of the shelf south of Hatteras in depths up to 100 fathoms, while pots are set for crabs inshore, and for black sea bass on rocks off Capes Hatteras, Lookout, and Fear. It is conceivable but unlikely that these latter two gear types could become entangled in pipelines and nearby debris.

While most fishing activity off North Carolina takes place landward of the 100-fathom contour, there are currently a few fisheries in deeper waters and the potential for several more to develop. Squid are fished north of Hatteras in about 100 fathoms, primarily by foreign vessels. Bottom trawls are used during the day, and mid-water or surface trawls employed at night. There is also a small lobster pot fishery in 100 to 150 fathoms, extending north from about 30 miles north of Hatteras, that also takes some cancer crabs. It is possible that a bottom long-line fishery for tilefish may develop in depths greater than 100 fathoms, and a fishery for red crabs in 250-350 fathoms.

Of the different gear types, bottom trawl gear is used most extensively in North Carolina, particularly offshore where pipelines and associated debris are more likely to be exposed. Consequently, the following discussion will focus on that type of gear. While conflicts with other gear (particularly dredges) may arise, these are not expected to be as frequent or costly.

Conflicts between pipelines and bottom trawling arise from three sources:

1) damage to trawl gear caused by the pipeline itself;
2) damage to gear from snagging on debris generated by the pipelaying operation; and
3) loss of fishing access as a result of avoiding the above two hazards.

Trawl Hazards Created by the Pipeline. Concern for the effects of exposed pipelines on trawl gear arises from two possible causes of damage: hooking of the trawl doors on the pipeline, and snagging of the net on various pipeline parts. In connection with the design of the FLAGS gasline built by Shell from the North Sea Brent field to St. Fergus, Scotland, several studies of trawl gear-pipeline interactions were conducted at the VHL River and Harbour Laboratory at the Norwegian Institute of Technology in Trondheim, Norway. The series of laboratory and field studies focussed on the effects of trawl door impacts on pipelines and yielded the following conclusions regarding trawl door behavior:

- When a pipeline was struck by a trawl board in its normal upright position, the board passed over the pipeline and resumed its upright position, regardless of whether the pipeline was lying on the seabed, in a trench, or spanned.

- Hooking of the board may occur if the board strikes the pipeline at an angle, is lying flat on the seabed at contact, or catches under a spanned length. As tension in the tow warp increases, the board usually frees itself, but the boat instead may be pulled to a stop (if going slowly enough), or the warp may snap, not only resulting in the loss of gear, but also possibly injuring crew on the ship's deck.

- In one case, the elasticity of the tow warp caused a momentarily hooked board to free itself, "take flight" for several meters, and bury itself so deeply in the sediments that the warp broke.

- Pullover loads (tow warp tension) created when trawl doors contacted pipelines tended to be greater for lines in open trenches than for those resting on the seabed. Trenching without burial therefore may increase the potential for tow warps to break. (Gjorsvik et al., 1975; Moshagen and Kjeldsen, 1980; Gowen et al., 1980; Centaur Associates, 1981).

Regarding trawl nets themselves, damage by pipelines has been reported as a result of snagging on exposed valves and anodes, damaged areas of the concrete coating, and steel bands and sheet metal covers used at pipeline field joints, particularly when the latter are torn by jet sleds during trenching (Strating, 1981; Centaur Associates, 1981).

Federal regulations at 43 C.F.R. §3340.1 require that pipelines present no unreasonable obstruction to fishing, and OCS Order No. 9 states that pipelines must be compatible with trawling operations. The standard solution to pipeline-gear conflicts has been to bury the line. Otter trawl boards penetrate the bottom no more than 5-10 in., and hydraulic dredges only 6-12 in. (Centaur Associates, 1981), so that burial of the pipeline as little as 2 feet below the mud surface would effectively eliminate the problem.

The general policy of MMS in the Gulf has been to require pipeline burial to a minimum of 3 feet below the mudline out to water depths of 200 feet. In addition, all taps and valves at any water depth must be installed a minimum of 3 feet below the mudline unless approved valve covers are used, in which case the top of the protective cover must not protrude above the mudline (USDOI/BLM, 1981a). Two hundred feet was chosen as the seaward limit of burial because most commercial bottom fishing activity in the Gulf (primarily shrimp trawling) takes place in shallower water depths. In state waters, Louisiana requires burial 3-6 feet below the mudline.

Unfortunately problems often arise in that natural backfilling of the trench, relied on to actually cover the pipeline, may not occur, or the pipeline may become unburied as a result of scour, liquefaction, or other means. Bottom currents in deep waters of the North Sea, for instance, were found to be insufficient to backfill trenches naturally. Where backfilling fails to occur, studies by Shell have indicated that entrenchment of the pipeline may create more trawling hazards than would placement of the pipeline on the undisturbed seafloor (Broussard, 1979). As mentioned above, for instance, Moshagen and Kjeldsen (1980) reported that trawl door pullover forces for trenched but unburied pipelines were at least as high as, and sometimes greater than, those for untrenched lines. Moreover, jet sleds may damage the pipeline's concrete coating and field joint covers, and trenching and bury barge anchors may expose additional debris, all of which may damage nets (see Figure 8-1).

Artificial backfilling, while promising, has problems of its own. When portions of the Ekofisk to Emden gasline in the North Sea failed to be buried by natural backfilling, the Danish government required the operator to artificially bury the line with crushed stone, at substantial expense. Since then, fishermen trawling over the line have reported that the stone collects in the cod end of their nets, wears a hole, and releases the catch, leaving them with damaged gear and nowhere to go for compensation (Nothdurft, 1980).

An alternative or supplement to burial is the design of a smooth pipeline surface intended to minimize the potential for net hangs. Valves are commonly guarded with a small dome or cage or are cemented in for protection against nets (Dames and Moore, 1981). For Lease Sale 48 in southern California, Stipulation No. 4 required that

> "All pipelines, unless buried, including gathering lines, shall have a smooth-surface design. In the event that an irregular pipe surface is unavoidable due to the need for valves, anodes, or other structures, they shall be protected by shrouds which will allow trawl gear to pass over the object without snagging or otherwise damaging the structure or the fishing gear."

By way of summarizing the various studies and experience, current evidence suggests that pipeline-gear interactions may best be minimized in the following manner:

- regardless of location, the pipline should be designed with a smooth surface, including appropriate valve covers;
- where field studies indicate that currents and available sediment supplies are sufficient to backfill the trench naturally, or where backfilling with endemic materials can be readily accomplished, the

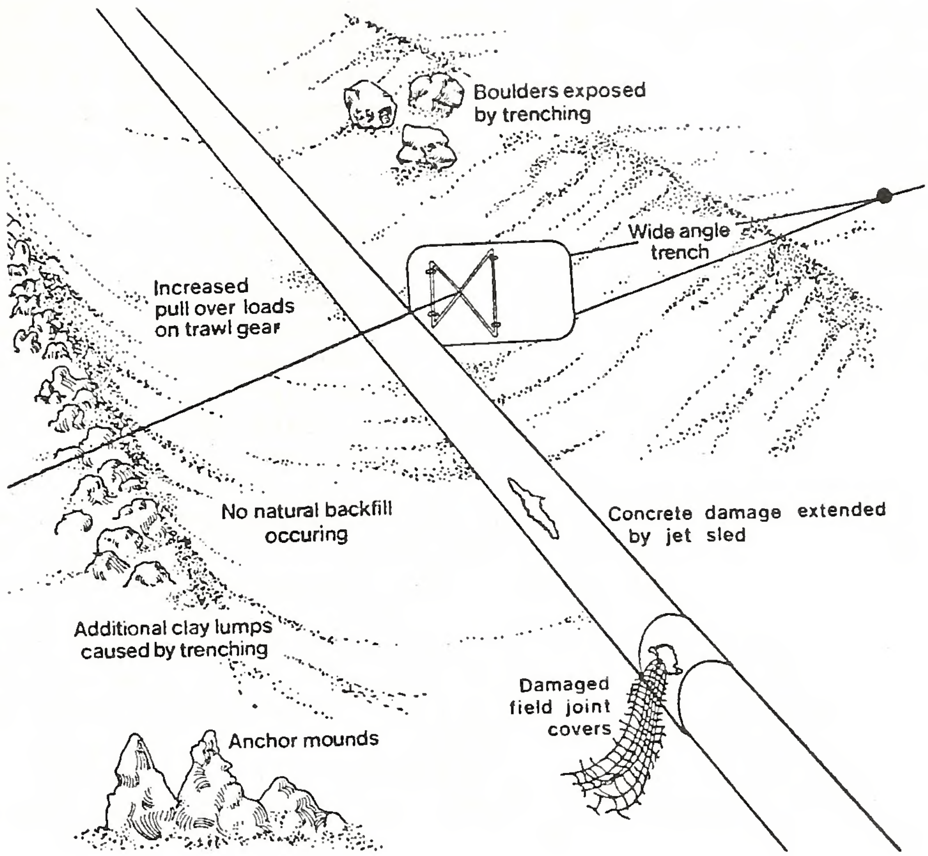


Figure 8-1. Trawling hazards created by trenching. (from Broussard, 1979)

pipeline should be buried at least 2-3 feet below the mudline;

- where currents are not sufficient, the pipeline should be laid snugly on the seabed.

These precautions are only necessary within areas of trawling activity. Off North Carolina, trawling regularly occurs out to 90 meters (300 ft.) and often to 183 meters (600 ft.); i.e., in substantially deeper waters than in the Gulf.

Debris Hazards. In addition to the pipeline itself, a variety of debris often left behind by pipelaying operations may snag and damage trawl gear. Debris was the cause of the most emotional oil-fishing conflict in the North Sea (Nothdurft, 1980), and is a problem in all offshore drilling areas. Hazardous debris is of two main types: boulders and heaps of heavy clay exposed by trenching activities, and debris or refuse lost or dumped overboard by pipeline contractors during construction, including oil drums, scrap metal, lengths of steel cable, pipe turnings, and heavy equipment cheaper to dump overboard than repair.

OCS Order No. 1 requires that the ownership of all subsea objects and of all objects and equipment used on rigs and vessels that might be lost

overboard be labelled, so that responsibility for recovered debris can be determined. However, such a measure is not sufficient in itself to ensure that adequate precautions and necessary clean-up operations will be undertaken to eliminate debris. Debris-control programs should be designed by each pipeline operator with the objective of leaving behind as clean and smooth a surface as possible.

The Norwegian government has been responsible for the most comprehensive debris survey and clean-up program to date. In response to fishermen's complaints and a study of its own, the Petroleum Directorate ordered Norpipe and Phillips to resurvey pipelines from the Ekofisk field and identify and retrieve all objects along the route. The work was done using both side-scan sonar and submersibles at a cost of approximately $4 million. As a result of its experience, Norpipe has recommended a standard debris clause for pipeline construction contracts:

> "During the work, Contractor shall not dispose of any material into the sea or air, which can be of danger to or interfere with other marine activity or life. The sea floor, sea, or air shall not be contaminated.
>
> "As soon as the work is completed, the seabed shall, if practical, be brought back to original condition and Contractor shall clear the premises of debris, waste material, and equipment remaining from the work. Nothing shall be left which can interfere with fishing, marine, or other activity. All material belonging to Company shall be loaded for storage or to a location as directed by the Company Representative."
>
> "Contractor shall be responsible for the recovery of any debris it dumps and shall bear the cost of such recovery operations." (Nothdurft, 1980)

Loss of Access. A complementary concern to the trawling hazards discussed above is whether the desire to avoid such hazards results in a loss of fishing access to a swath of seabed along the pipeline route. Evidence from the North Sea, Gulf of Mexico, and Southern California indicates that trawl fishermen in general do not avoid entire pipeline routes. In the North Sea and Gulf, fishermen regularly trawl across pipeline routes even though the pipelines may not be buried and in spite of the fact that in the North Sea compensation will not be paid should gear damage result. In the Santa Barbara channel, it is believed that pipelines attract fish (due to the slight change in bottom relief and/or the warmth or noise associated with flowing oil), and fishermen specifically trawl along the routes of unburied lines (Centaur Associates, 1981).

On the other hand, particular pipeline segments are avoided by trawl fishermen if specific obstructions are known to exist, as discovered by trial and error (Dunham, 1981). Such knowledge may be passed on from one captain to another, or recorded on charts and in various publications. Centaur Associates (1981) evaluated the various factors involved in determining how wide a berth fishermen must give to known subsurface obstructions. Factors considered include vessel maneuverability, gear placement and control, weather and sea conditions, navigational accuracy and others. Their conclusion was that the upper limit for a buffer zone needed to avoid subsurface obstructions is set by the upper limit of accuracy of Loran C navigation, commonly accepted as 1320 feet (one-quarter mile). The Fishermen's Contingency Fund (discussed

shortly) also has a one-quarter mile limit, within which distance from recorded obstructions the fund will not pay compensation for damages. Fishermen wishing to avoid gear loss ineligible for compensation from the fund will give such obstructions a one-quarter mile berth, resulting in the loss to trawling access of roughly 0.2 square mile of seabed for each obstruction.

The conclusion that can be drawn from experience elsewhere is that there will be some loss of fishing area for some fishermen as a result of pipeline construction. This will range from virtually no loss for risk-taking captains, to the loss of one-quarter mile buffer zones around known obstructions for prudent captains, to the avoidance of the entire pipeline route by cautious fishermen, at least until experience by others indicates its safety.

The OCS Lands Act Amendments of 1978 (43 U.S.C. §§1841 et seq.) established two programs designed to reduce the risk and uncertainty involved in fishing waters used for oil and gas exploration and production. The more important of the two, the Fishermen's Contingency Fund, was established to compensate fishermen for gear loss or damage by OCS oil- and gas-related obstructions. The program is funded by assessments collected from holders of OCS lease tracts, exploration permits, and pipeline rights-of-way, and is administered by the National Marine Fisheries Service.

In general, the fund provides compensation both for damages to gear and vessels and for resulting losses of income attributable to oil- and gas-related obstructions. Since it may be difficult or impossible for a fisherman to identify the cause of the damage, the legislation establishes a presumption that damages were caused by OCS petroleum activities if the fisherman can establish that:

1) The vessel was being used for commercial fishing in an area affected by OCS oil and gas activities;

2) appropriate reports were timely filed; and

3) there was no record of an obstruction in the immediate vicinity (established by regulations as within one-quarter mile) as shown on the most recent National Ocean Survey nautical charts, in the weekly Notice to Mariners, or by a proper surface marker or lighted buoy.

The program has experienced substantial growing pains and has been slow to become fully operational. Final regulations were not published until January 1980, more than 17 months after the law's enactment. The regulations that were promulgated proved to be cumbersome and confusing, resulting in lengthy delays in processing claims (often over a year) and in confusion and frustration on the part of fishermen trying to meet the filing requirements. In response to these and other problems, new interim regulations were published in the Federal Register on December 8, 1981, that were designed to reduce processing time by several months. In addition, legislation was introduced and recently passed by Congress (P.L. 97-212, signed into law June 30, 1982) to further simplify procedural requirements, to provide fishermen with more time to file claims, to extend coverage of the program to all areas affected by OCS activities, and to make other adjustments needed in the program. It is the expectation of most parties concerned that the program should now begin to function efficiently (Montgomery, 1982; Lanjillo, 1982). To help ensure the program's effectiveness locally, the State of North Carolina, perhaps through Sea Grant's extension services or the Division of

Marine Fisheries, should consider providing help to fishermen in understanding the purposes and coverage of the program and its filing requirements.

The second program created under authority of the OCS Lands Act Amendments of 1978 is the OCS Bottom Obstruction Program administered by the National Ocean Survey (NOS) in NOAA. The purpose of the program is to develop fishing obstruction charts covering OCS lease sale areas from data compiled by fishermen, the oil industry, and others. It was intended that data collected would be verified by private surveyors using a combination of electronic instrumentation and conventional wire-drag techiques, and that the results would be published on Fishing Obstruction Charts for various OCS regions, with obvious potential for reducing oil- and gas-related gear damage (Dames and Moore, 1981).

In practice, the Office of Management and Budget has refused National Ocean Survey requests for funding of surveys and chart preparation. Currently NOS collects obstruction data, publishes it in Notice to Mariners, and stands ready to assist states in any related work they wish to undertake, but no surveys or charts are currently planned (Montgomery, 1982). In response to OMB's action, however, Congress, in the recently passed amendments to the Contingency Fund program, directed the Secretary of Commerce to conduct such surveys within two years of the amendments' enactment.

The University of North Carolina Sea Grant Program has published a list of hangs and obstructions along the Atlantic coast taken from the logs of trawler captains, with most complete coverage between Virginia and Georgia (McGee and Tillett, 1979). It is intended that this list will be updated periodically, and in the absence of any additional federal effort, this list and the Notice to Mariners together will offer the best source of information on bottom trawling obstructions.

8.2 RECREATIONAL FISHING

Approximately one million people participated in salt water sport fishing in North Carolina in 1979, according to a nationwide survey of marine recreational fishing conducted by the National Marine Fisheries Service (USDOC/NMFS, 1980). The estimated numbers caught of each species are shown in Table 8-4, and the proportions caught by area and mode of fishing for the southeast region as a whole are presented in Table 8-5. The large majority of fish landed were estuarine and nearshore species taken at piers, from the surf, or from small boats in the sounds.

The charter boat and head boat fisheries in North Carolina have recently been described by Manooch et al. (1981) and Huntsman (1976), respectively. Table 8-6 lists the estimated catch of charter boat fishermen in 1978, taken during a total of 9800 trips (86% trolling, 12% bottom fishing on reefs, and 1% each fishing in estuaries and carrying divers). Major charter boat ports are Kitty Hawk, Manteo, Wanchese, Hatteras, Ocracoke, Morehead City, Atlantic Beach, Swansboro, Sneads Ferry, Carolina Beach and Southport (USDOI/BLM, 1981c).

Further information on the receational fisheries of this area is contained in the reviews by Chenoweth (1977) and Martin (1979). In addition, two guides to marine sport fishing on the North Carolina coast have been

Table 8-4. Estimated Total Number of Fish Caught by Marine Recreational Fishermen in North Carolina by Species Group, Jan. 1979-Dec. 1979.

Species Group	Fish Caught (Thousands)	Species Group	Fish Caught (Thousands)
Barracudas	-	Perch, White	67
Basses, Sea	2,033	Pigfish	368
Bluefish	3,085	Pinfish	569
Blue Runner	*	Porgies	30
Bonito, Atlantic	-	Puffers	-
Catfishes, Sea	-	Scup	-
Croaker, Atlantic	3,259	Searobins	593
Dolphins	-	Seatrout, Sand	*
Drum, Black	-	Seatrout, Silver	514
Drum, Red	-	Seatrout, Spotted	-
Drums	-	Sharks	137
Eel, American	-	Sharks, Dogfish	50
Flounders, Summer	711	Sheepshead	-
Flounders	-	Skates and Rays	76
Groupers	-	Snapper, Gray	*
Grunt, White	-	Snapper, Red	*
Grunts	*	Snapper, Vermillion	-
Hakes	*	Snappers	-
Herrings	64	Spadefish, Atlantic	*
Jack, Crevalle	133	Spot	7,786
Jacks	165	Striped Bass	38
Kingfishes	438	Tautog	-
Ladyfish	*	Toadfishes	-
Little Tunny	*	Trigger and Filefishes	45
Mackerel, King	-	Weakfish	-
Mackerel, Spanish	46	Other Fish	1,653
Mackerels and Tunas	*		
Mullets	-	Total	22,159
Perch, Sand	*		
Perch, Silver	99		

Note: An asterisk (*) denotes none reported.
A dash (-) denotes less than thirty thousand reported. However, the figure is included in the column total.

Source: U.S. Dept. of Commerce, National Marine Fisheries Service, 1980.

published (Freeman and Walford, 1976; Alexandria Drafting Company, 1981), and these provide a wealth of information on recommended fishing locations and methods.

As with commercial fisheries, pipeline impacts on recreational fishing fall into two main categories: impacts on fishing activities and impacts on fish stocks. In-place pipelines will not interfere with the hook-and-line gear of recreational fishermen, and the only impacts on fishing activities will be interference during the pipelaying operation. At the landfall site, a stretch of beach 50 to 100 meters long will be closed to surf casters for several weeks, and pipelaying offshore over hard bottoms will displace fishermen from these rocks for a day or two at any one location. Such impacts will be minor and temporary, if they occur at all. Since fishing activities are seasonal, interference could be avoided by appropriate scheduling. Unfortunately, autumn beach landfall construction, desirable to avoid summer bathing use and to coordinate clean-up operations with preferred dune planting times, will conflict directly with the most popular surf fishing season. The length of beach affected will be relatively insignificant, except where construction blocks access to additional fishing areas beyond the site.

Table 8-5. Estimated Total Number of Fish Caught by Marine Recreational Fishermen in the South Atlantic Region, by Area and Mode of Fishing, 1979.

Area	Fish Caught (Thousands)	Percentage of Total
Ocean: More than 3 miles	12,404	18.8%
Ocean: 3 miles or less	25,702	38.9
Inland	15,787	23.9
Unknown	12,241	18.5
Total	66,135	100.1
Mode		
Man-Made	20,127	30.4%
Beach/Bank	10,899	16.5
Party/Charter	1,737	2.6
Private/Rental	33,372	50.5
All Modes	66,135	100.0

Source: U.S. Dept. of Commerce, National Marine Fisheries Service, 1980.

Table 8-6. Fish caught by North Carolina charter boat anglers in 1978, ranked in order of pounds and indicating major type of fishing category. (Source: Manooch et al., 1981)

Species	Pounds	Fishing category
King mackerel, *Scomberomorus cavalla*	446,741	Trolling
Dolphin, *Coryphaena hippurus*	274,993	Trotling - offshore
Bluefish, *Pomatomus saltatrix*	262,699	Trolling - inshore and Bottom fishing - estuaries
Yellowfin tuna, *Thunnus albacares*	151,252	Trolling - offshore
White marlin, *Tetrapturus albidus*	[1]142,844	Trolling - offshore
Black sea bass, *Centropristis striata*	141,162	Bottom fishing - offshore
Blue marlin, *Makaira nigricans*	[1]82,585	Trolling - offshore
Wahoo, *Acanthocybium solanderi*	73,603	Trolling - offshore
Amberjacks, *Seriola*	45,433	Trolling and Bottom fishing - offshore
Red Porgy, *Pagrus pagrus*	38,066	Bottom fishing - offshore
Blackfin tuna, *Thunnus atlanticus*	37,904	Trolling - offshore
Little tunny, *Euthynnus alletteratus*	37,850	Trolling
White grunt, *Haemulon plumieri*	16,606	Bottom fishing - offshore
Sailfish, *Istiophorus platypterus*	[1]16,189	Trolling - offshore
Groupers, *Mycteroperca* and *Epinephelus*	15,632	Bottom fishing - offshore
Spanish mackerel, *Scomberomorus maculatus*	12,397	Trolling - inshore
Sharks, *Carcharhinus*	10,577	Trolling and Bottom fishing - offshore
Atlantic bonito, *Sarda sarda*	9,338	Trolling
Great barracuda, *Sphyraena barracuda*	7,376	Trolling
Skipjack tuna, *Euthynnus pelamis*	7,214	Trolling - offshore
Vermilion snapper, *Rhomboplites aurorubens*	6,468	Bottom fishing - offshore
Flounders, *Paralichthys*	2,230	Bottom fishing - estuaries
Cobia, *Rachycentron canadum*	1,910	Trolling
Bluefin tuna, *Thunnus thynnus*	1,667	Trolling - offshore
Weakfish, *Cynoscion regalis*	1,307	Bottom fishing - estuaries
Gray triggerfish, *Balistes capriscus*	1,192	Bottom fishing - offshore
Atlantic croaker, *Micropogon undulatus*	1,004	Bottom fishing - estuaries
Red drum, *Sciaenops ocellata*	819	Bottom fishing - estuaries
Spot, *Leiostomus xanthurus*	572	Bottom fishing - estuaries
Bigeye tuna, *Thunnus obesus*	558	Trolling - offshore
Albacore, *Thunnus alalunga*	428	Trolling - offshore
Red snapper, *Lutjanus campechanus*	382	Bottom fishing - offshore
Longbill spearfish, *Tetrapturus pfluegeri*	370	Trolling - offshore
Frigate mackerel, *Auxis thazard*	326	Trolling - inshore
Crevalle jack, *Caranx hippos*	28	Trolling - inshore
Bar jack, *Caranx ruber*	4	Trolling - inshore
Totals	1,849,726	

[1]Includes fish that were officially caught and then released. Weights were expanded for released fish based on mean weight for each species obtained by dockside samples.

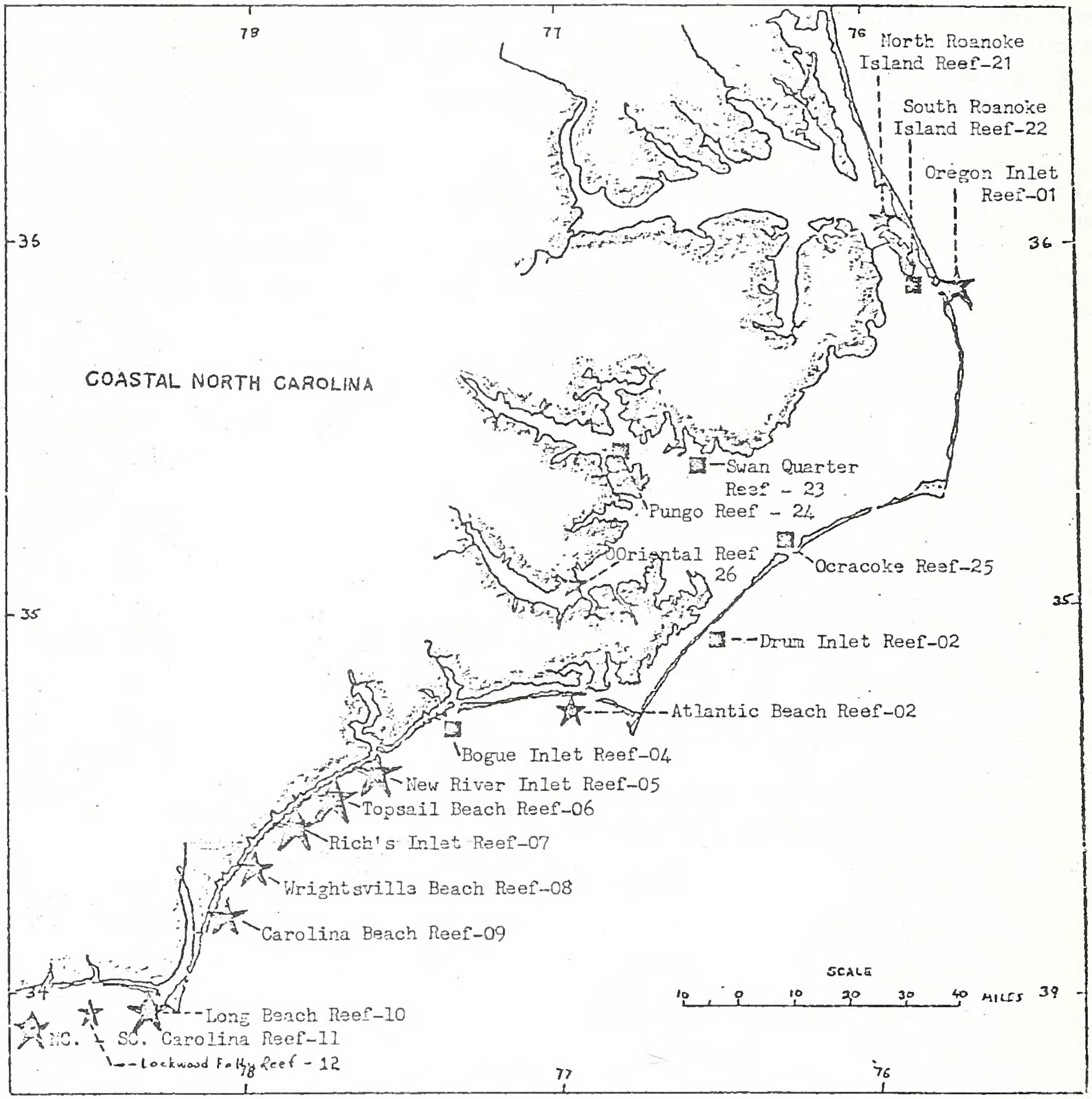
Potential impacts of pipelines on fish stocks have already been covered in the sections on estuaries, offshore waters, and commercial fishing. They will not be discussed further here, except to note that the most significant adverse effects on recreational fisheries will occur if and where important estuarine and offshore habitats (primary nursery areas, grass beds, shellfish beds, live bottoms) are altered by trenching and burial. Where the pipeline can be left unburied, on the other hand, it may act as an artificial reef and so enhance recreational fishing along its route.

In addition to the natural reefs and live bottoms scattered across the Carolina shelf, several artificial reefs have been constructed in state waters, mostly by the N.C. Division of Marine Fisheries, to enhance sport fishing (Table 8-7, Figure 8-2). The reefs are all relatively small in area, and there should be no difficulty in routing pipelines to avoid these locations.

Table 8-7. Artificial reefs in North Carolina.

Reef	Construction Began	Materials	Depth
North Roanoke Island	1973-74	150 tires	12 ft.
Oregon Inlet	1974	two 440 ft. liberty ships 83 ft. trawler	72 ft. 45 ft. cl.
Oriental	1973-74	10,000 tires	12 ft.
Atlantic Beach	1974	440 ft. liberty ship 79,400 tires 40 ft. Coast Guard launch local effort: 1,500 tons of concrete chunks and 1,000 tires about 3/4 mile south of buoy	50 ft. 20 ft. cl.
New River	1975	5,172 tires	33 ft.
Topsail Beach	1974	48,700 tires	43 ft.
Rich's Inlet	1974	66,500 tires	42 ft.
Wrightsville Beach	1970	440 ft. liberty ship 135 ft. barge 188,800 tires local effort: 110 ft. tug, 50 ft. tankers, two 90 ft barges, 56,500 tires	50 ft. 20 ft. cl.
Carolina Beach	1981	98 ft. barge	
Long Beach	1974	50,000 tires	30 ft.
Lockwoods Folly	1972	8,000 tires local effort: 1,500 tires two 28 ft. life boats	42 ft.
Little River	1975	24,000 tires	35 ft.

Data current as of March 1, 1982. Source: N.C. Division of Marine Fisheries.



☆ -- Existing reefs to be expanded.

☐ -- Proposed reef sites.

Figure 8-2. Artificial reefs in North Carolina. (from N.C. Division of Marine Fisheries)

8.3 NAVIGATION AND SHIPPING

The North Carolina coastal area is richly endowed with a system of ports and waterways that accommodates a large volume of commercial shipping and substantial fleets of commercial and recreational fishing vessels and pleasure craft. Over 60% of the state's waterborne tonnage passes through the state's two deepwater ports, at Wilmington and Morehead City, where the State Ports Authority maintains shipping terminal facilities (Table 8-8). The Atlantic Intracoastal Waterway and the lower, navigable reaches of several coastal plain rivers account for the remainder. In addition, there are many smaller harbors and channels used by commercial and recreational fishermen and recreational boaters. In all, the Corps maintains approximately 1500 miles of navigable waterways in coastal North Carolina (Holliday, 1982).

Table 8-8. Summary of Shipping Through Major Waterways and Ports in North Carolina, 1979.

	Freight (Thousands of Short Tons)		No. of Vessels[1]	
Wilmington	9577		6374	
Morehead City	3569		8822	
Atlantic Intracoastal Waterway	3719		64,854 northbound	
			50,922 southbound	
Navigable Rivers	2926		7543	
Pamlico/Tar		1321		1320
Chowan		303		3561
Roanoke		301		1520
Cape Fear		403		653
Northeast (Cape Fear)		597		489

1. Average of inbound and outbound (or upbound and downbound) vessel totals, except for the Intracoastal Waterway.

Source: U.S. Army Corps of Engineers, 1981.

There are three sources of potential conflict between the navigational use of coastal waters and the construction and operation of pipelines: 1) the obstruction or hazard presented by pipelaying operations to surface vessel traffic; 2) the obstruction or hazard of the pipeline itself; and 3) the obstruction or hazard presented by any offshore booster station platform that may be constructed. The latter item will be discussed in Section 9.2 on ancillary facilities, and the former two are examined below.

8.3.1 The Obstruction or Hazard Presented by Pipelaying Operations

Pipelaying and bury barges and their associated tugs, supply vessels, and other support ships present a source of interference to existing vessel traffic. The hazard results not only from the increase in the number of

vessels operating in a particular area, but also from the fact that the barges and their tugs may cross accustomed travel routes, and that lay and bury barges have very little mobility. Matters of marine safety are the primary responsibility of the U.S. Coast Guard, and responsibility for North Carolina coastal and offshore waters is divided between the 5th District Office in Portsmouth, Virginia, and the Captains of the Port at Wilmington, N.C., and Hampton Roads, Va.

Under the Port and Tanker Safety Act of 1978 (P.L. 95-474), the Secretary of Transportation is authorized to designate fairways and traffic separation schemes within which navigation would have the paramount right over other uses of the area, wherever such designation is necessary to ensure safe vessel access to ports and waterways. Such designations must be preceded by a port access route study that examines all other potential uses of the study area, including OCS oil and gas development. The Fifth Coast Guard District issued its port access routes study for the area including waters off North Carolina in July 1981. Among the report's conclusions are:

"c. That there are safe access routes to the ports of the Fifth Coast Guard District for the present and future projected amount of vessel traffic using those ports...

"e. That during the next five year period of time, the anticipated use and development of the natural resources found on that portion of the Outer Continental Shelf located within the coastal waters of the Fifth Coast Guard District will not interfere with the navigation on those waters,..." with the exception of development of the six tracts off Cape Lookout (no longer scheduled for leasing). (USDOT/CG, 1981)

There are, of course, several heavily used shipping routes and waterways along the North Carolina coast that might be crossed by pipelaying operations, including approaches to the two major ports at Wilmington and Morehead City, the major north-south routes passing Diamond Shoals light southeast of Cape Hatteras, and the Atlantic Intracoastal Waterway. Careful planning and coordination with the Coast Guard will be necessary to minimize safety hazards and potential interference with shipping schedules. Measures generally used to accomplish these ends include notices in the Local Notice to Mariners and on marine broadcasts, appropriate scheduling of waterway crossings, proper lighting, etc. An alternative to standard river crossing procedures for heavily used waterways is the recently developed method of directional drilling, described in Chapter III. This technique has been used in pipeline crossings of the Houston Ship Channel, the Mississippi River, and other major waterways, and one of its prime advantages is that it eliminates all interference with waterway traffic.

Provided these measures are taken, collision hazard should be reduced to a bare minimum. During the decades of work in the federal sector of the Gulf of Mexico, there is no record of any collision with pipeline construction vessels (USDOI/BLM, 1981d).

Mention should be made of the potentially large increases in barge traffic that may occur along certain routes in the future. Because of rail and port congestion, increasing attention is being paid to the use of barges to transport coal and phosphate from upriver terminals to existing or new port facilities, or directly to barge-carrying vessels or ships equipped for mid-stream transfer. A recent report (Cribbins and Latta, 1982) identified

the use of barges to transport coal from railheads on the Pamlico or Neuse River to Morehead City harbor as one of the most promising means to alleviate current rail congestion and its accompanying social impact. Such increases in barge traffic should not create overwhelming obstacles to pipelaying operations, but early coordination with operators of the barge fleet will be necessary to avoid conflicts.

8.3.2 Obstructions and Hazards Presented by the Pipeline Itself. Shipping activities that disturb the bottom may damage pipelines, whose spilling contents, in turn, create a hazard for surface vessels. The primary bottom disturbing activity of marine vessels is the use of anchors and particularly dragging anchors, although other activities, such as the loss of material overboard or the grounding or sinking of a vessel, may also endanger pipelines.

The subject of hazards to pipelines from anchors is reviewed in Chapter IX. The conclusion of that discussion, based on current evidence, is that most commercial vessel anchors bury 0.5 to 3.3 meters (1.5 to 9.9 ft.) into the sediment, and that pipeline burial to depths of 3 meters or more will effectively protect pipelines from these anchors. The anchors of large tankers and oil-related vessels (derrick barges, lay barges, etc.), on the other hand, may penetrate from 5 to 17 meters in good holding ground and even deeper in soft clays. In view of these depths, there is no currently feasible way to protect pipelines from anchors this size.

Short of routing pipelines away from areas of intense tanker and rig traffic (often impractical or needlessly expensive), there are several other, far less costly precautions that can be taken to achieve a reasonable margin of safety. These include the dissemination to all appropriate parties of accurate pipeline location maps, and specific procedures and on-site monitoring by the pipeline operator for all operations in the pipeline's vicinity.

The degree of hazard from anchors depends, of course, on where vessels are likely to anchor. The U.S. Coast Pilot (USDOC/NOAA, 1980) lists three commonly used anchorages for large ships in North Carolina waters: Lookout Bight, Beaufort Inlet, and the Cape Fear River. In addition, there is an exclusive anchorage (established by regulation, 33 C.F.R. §110.170) lying off Holden Beach, in Brunswick County, for ships carrying explosives to Sunny Point Military Ocean Terminal. All four of these areas would be best avoided by pipelines. Should a pipeline route be proposed through one of these areas, the applicant should furnish information on the types of vessels commonly using the anchorage, the expected depth of penetration of anchors in the sediments present, and the means to be used to bury a pipeline safely under that depth or to otherwise protect the line.

For the most part, vessels do not anchor on the open shelf, even in cases of equipment failure (Nothdurft, 1980). Oil-related vessels, mentioned above, are one exception; another exception are fishing boats that anchor while fishing the rock outcrops and coral patches off the Carolina coast. Pipelines should be designed with these latter vessels in mind. In inland waters, anchoring is prohibited by regulation (33 C.F.R. §162.65) "within areas occupied by submarine cable or pipe crossings," except in cases of emergencies.

As mentioned above, other bottom disturbances can rupture pipelines in addition to dragging anchors; these include material lost overboard and vessel groundings and sinkings. These disturbances are most common along heavily used waterways, and for this reason, as well as to avoid interference with dredging operations, pipeline burial requirements established by the Corps of Engineers for waterways are typically stricter than elsewhere. In the Gulf, for instance, the New Orleans District requires pipelines crossing channels more than 30 feet in depth to be buried at least ten feet below the channel's maintenance depth or existing depth (whichever is greater), and ten feet below channel slopes as well. For channels less than 30 feet in depth, burial must be at least 8 feet below maintenance depth or 3 feet below the existing bed (whichever is deeper), and at least 8 feet below channel slopes (Lukos, 1982).

8.4 MINING

The presence of a large pipeline over economically recoverable mineral deposits may increase the expense of mining those deposits, and in extreme cases may make the mining venture financially unattractive. Conversely, mining operations in a pipeline's vicinity may pose a significant threat to the line's integrity. For these reasons, the location of mineral deposits needs to be considered in pipeline routing.

For purposes of discussion, the resources currently being mined in eastern North Carolina, or that may be mined within the lifetime of a hydrocarbon pipeline, are divided into three groups: 1) peat, 2) phosphate, and 3) sand, gravel, limestone, and cement.

Peat. Extensive deposits of peat occur throughout the eastern half of the North Carolina coastal plain (Figure 8-3). Formed in pocosin wetlands, these deposits are relatively shallow, ranging from 3-8 feet in depth. Their mining on a large scale for fuel only became financially feasible as a result of the last major round of oil price increases in 1979. Currently there are four approved mining permits for peat (three on the Pamlimarle peninsula and one in Pamlico County), and two more applications are pending.

Where peat deposits are to be mined, the land is first cleared and drained. Drainage is typically accomplished using a two-tiered system of canals. Large canals, spaced at one-mile intervals, are dug at least to the base of the peat and may extend ten feet below ground level. A series of smaller, feeder ditches are laid out in a grid pattern, spaced 100 to 150 yards apart. The fields are then graded, allowed to dry, and the top few inches of dried peat scraped off. The process of drying and scraping continues until the peat is removed; the land underneath may then be converted to productive farmland (Simons, 1982).

Pipeline crossings of minable peat deposits raise several concerns. Because of the shallowness of the peat deposits, it may be possible to place the pipeline under the peat and allow future mining to proceed over the line. If so, monitoring would be needed to guarantee adequate clearance between the mining equipment and the pipeline, and tests should be conducted to ensure that the weight of the equipment will not damage the line. It might be simpler for the pipeline operator to simply purchase the peat within the right-of-way and prohibit its mining. Current peat prices are in the neighborhood of \$5,000 - \$11,000 per acre-foot, in place. A long, linear

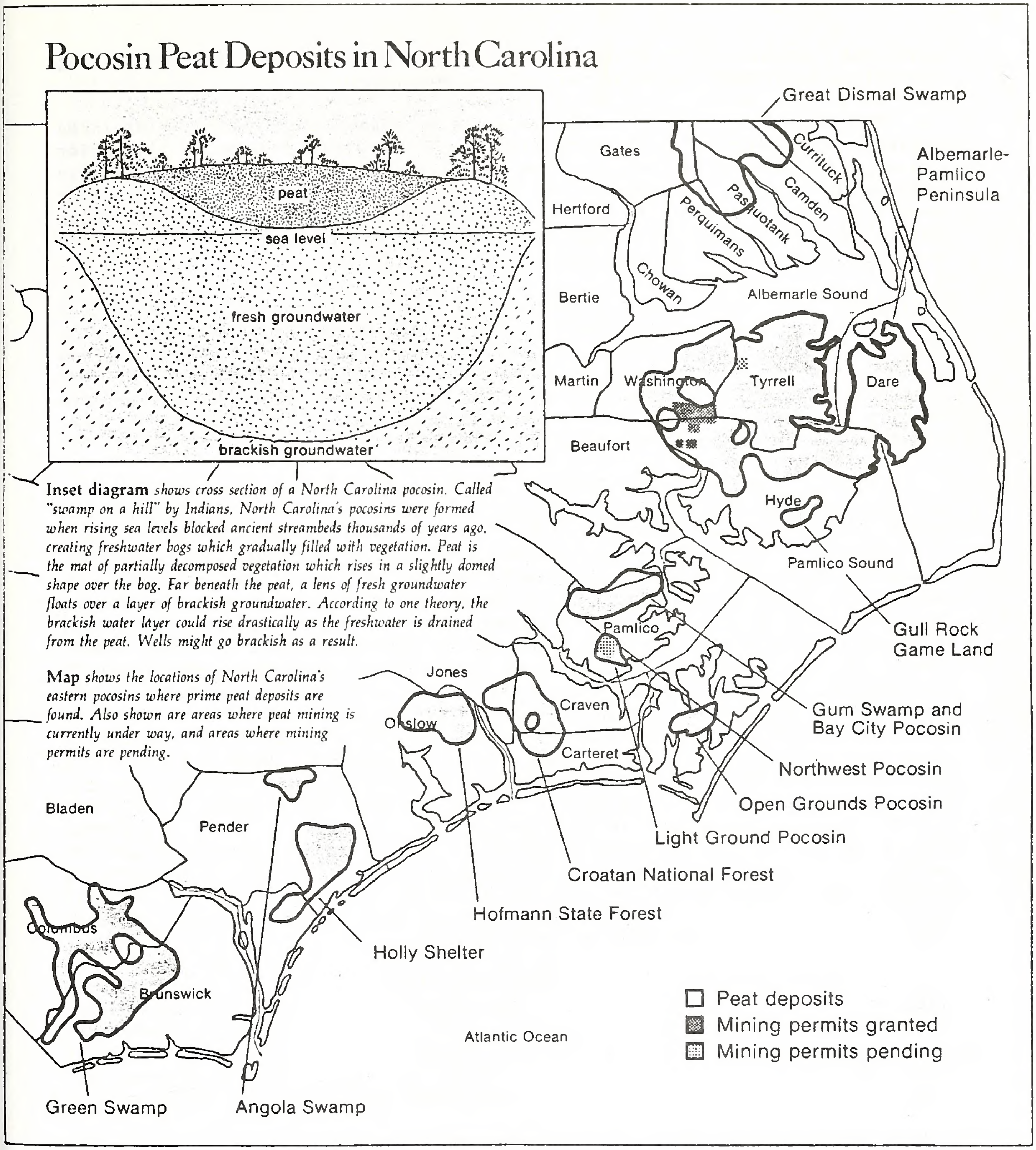


Figure 8-3. Pocosin peat deposits in North Carolina. (from Wildlife in North Carolina, 1981)

mound of unmined peat might present some inconvenience to the mining operation, but certainly would not be unsurmountable.

The other major concern will be avoiding interference with the drainage system. The pipeline will either have to be lowered beneath the major drainage ditches, requiring a trench as much as 15 feet deep, or drainage water will have to be pumped over the line. Maintaining an open pipeline trench of that depth in the peaty, waterlogged soil may be difficult. With careful attention paid in the planning stages it should be possible to resolve potential conflicts satisfactorily.

Phosphate. The Pungo River formation, of middle Miocene origin, underlies much of the eastern coastal plain of North Carolina at varying depths. The formation contains significant amounts of phosphate that in some locations reach economically attractive concentrations. Currently the only recovery technology available is open pit mining of the phosphate ore. Several factors combine to determine where such recovery is economical: the grade of the ore, its thickness, and its depth beneath the surface.

The only area in North Carolina where phosphate occurs with sufficient quality and thickness close enough to the ground surface to be recoverable under current market conditions is in southern Beaufort County. These deposits lie within a large area northwest of Aurora and north of Highway 33, extending west from South Creek to and under Durham Creek, and extending out under the Pamlico River as well. Texas Gulf Corp. opened up a mining operation here in the early 1960's, and their current operation, including mine pit, waste piles, settling ponds, etc., covers several thousand acres. The ore is excavated from a vast pit to depths of 140 feet below ground level. A second firm, North Carolina Phosphate, is due to begin its operation in the same area shortly. While it might be possible to select a route through the area described above that would not interfere with current or future mining plans, the existence of such a route cannot be assumed. Such a route would have to be worked out with Texas Gulf and N.C. Phsophate officials. Outside this area, open mining of phosphate within the next 50-60 years is unlikely (Brown, 1982). There are other locations in the coastal plain where even higher grades of ore occur, but these are found at depths too great for recovery by surface operations. Technology to recover this phosphate by pumping water down wells and pulling phosphate-rich water up is currently under development, but no pipeline conflicts are foreseen if this process becomes commercial and is used in North Carolina.

High grade phosphate ore also crops out in Onslow Bay, and the grade and lack of overburden make these deposits attractive (Pilkey and Luternauer, 1967; Riggs et al., 1982). However, the problems of mining this ore underwater and the environmental impacts entailed are expected to delay development of these reserves until at least the middle of the next century (Brown, 1982), and no conflicts with current OCS development are foreseen.

Other Resources. Sand, gravel and marl are excavated from many small pits throughout the coastal zone, in almost every county. These resources are so abundant and readily available that significant impacts as a result of a pipeline making some small deposits unavailable are highly unlikely. No offshore sand or gravel mining currently occurs or is expected in the foreseeable future.

Permits for four limestone quarries in the coastal zone have been issued for areas near New Bern, Belgrade, Castle Hayne, and Rocky Point. All are owned by Martin Marietta, and all but the Rocky Point site have been developed, producing stone for aggregate. In addition, Ideal Cement Co. has developed a cement quarry in Castle Hayne adjacent to the Martin Marietta site. All of these quaries are several hundred acres in extent. The resources they provide are not readily available elsewhere in the coastal zone, and to prevent any unnecessary restrictions on the expansion of these quarries, hydrocarbon pipelines should give them sufficient berth.

8.5 OCEAN DUMPING

The Marine Protection, Research and Sanctuaries Act of 1972 (33 U.S.C. §§1401-1444 and 16 U.S.C. §§1431-1434) prohibits the ocean dumping of any material except under permit from EPA (for non-dredged material) or from the Corps of Engineers (for dredge spoil). Permits are issued in accordance with criteria established by EPA regarding the effects of and the need for the proposed dumping. These criteria, along with program procedures, are set forth at 40 C.F.R. §§220-229.

Historically there has been very little dumping of non-dredged material wastes off the southeastern U.S. coast, and there are no current or planned disposal sites for such materials off North Carolina (Rogers, 1981). There are two interim dredged material sites in North Carolina waters, off Morehead City and Wilmington, used by the Corps for hopper dredge disposal of dredging spoil from the harbors of these two ports. The Wilmington site is in the final stages of EIS review; the size of the area is under negotiation, but in any case will be substantially less than the 29 nautical square miles currently used. The review process for the Morehead City site is somewhat different, and an environmental assessment is being conducted internally by the Corps. Final designation of both sites should come sometime in 1983. (Holliday, 1982)

Where a pipeline is to be routed through either disposal area, avoiding conflicts with dumping activities should be a relatively simple matter of coordinating dumping and pipelaying schedules. The potential use of these areas by pipelines raises two other questions that are more difficult to answer. First, what effects will periodic dumping of spoil have on pipeline integrity, and how stable will the spoil be, once it has settled? Second, do the dredged spoils contain any toxic substances, such that resuspension of spoil during pipeline burial may create a biological or health hazard? Regulations require a chemical analysis of material (other than sand size or larger) currently being dumped, but these regulations have only been in effect for a few years. What toxics may be present in spoil dumped before then, both in current and discontinued disposal areas, is not known. To some extent this can be inferred from a harbor's history, but sediment tests along the proposed route would also be appropriate. Both of these questions are of sufficient concern that route proposals through disposal areas should receive an extra measure of scrutiny.

More information on the disposal sites can be obtained from the Navigation Branch, U.S. Army Corps of Engineers, Wilmington District.

8.6 MILITARY ACTIVITIES

A variety of military activities are conducted both within North Carolina and in the waters offshore. Some will present absolute barriers to pipeline routing, others will create a degree of hazard, and still others call merely for some simple precautions. The subject can be divided for discussion into four categories of activities: offshore activities, nearshore restricted areas, onshore installations and unexploded ordnance.

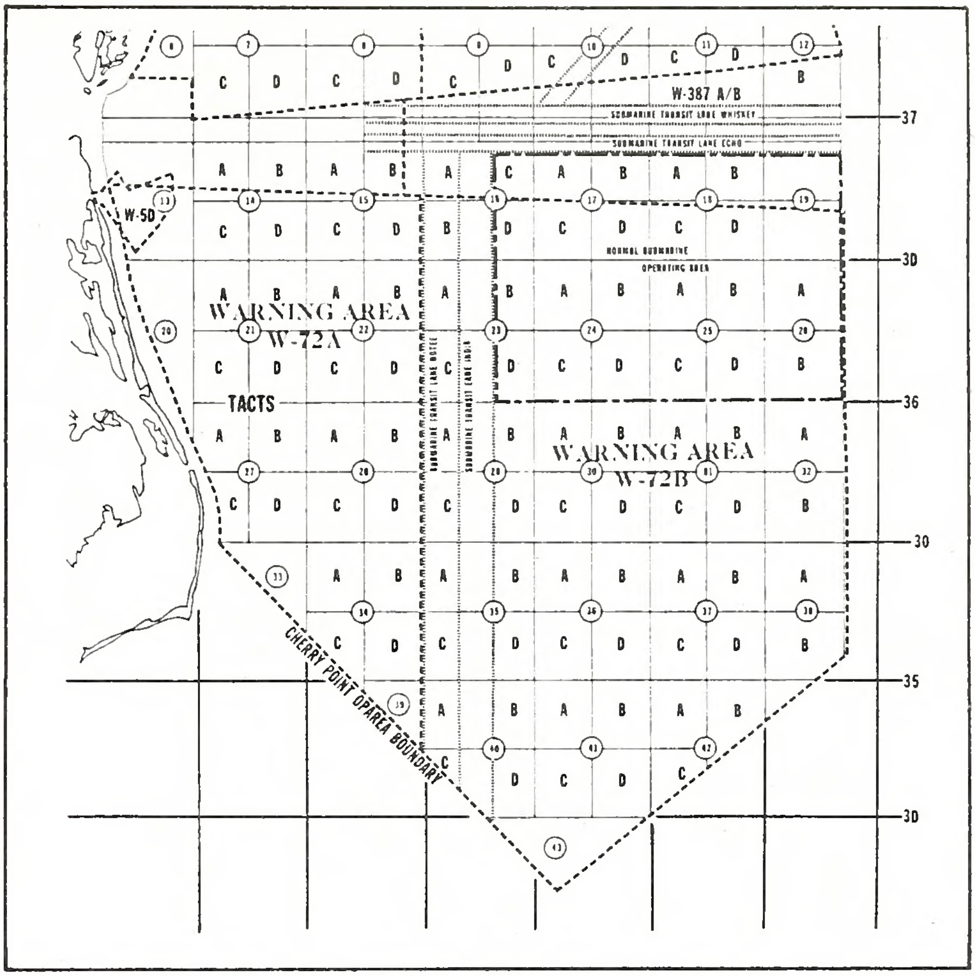
Offshore Activites. In regulations at 32 C.F.R. §252, the Department of Defense (DOD) sets forth its policy on offshore military activities. In general, DOD policy is that its use of offshore areas will be limited to that considered essential for military purposes, and that it will attempt to accommodate other uses of offshore areas in general, and oil and gas activities in particular, to the maximum extent feasible.

Several military departments or agencies operate regularly in these areas, including the Navy, Air Force, Army Corps of Engineers, Coast Guard, and NASA. Navy activities account for over 95% of all shelf military uses in the South Atlantic (Tibbetts, 1979), and these activities are under the jurisdiction of the Commander-in-Chief, U.S. Atlantic Fleet, Norfolk, Virginia.

CINCLANTFLT Instruction 3120.26B contains general information, instructions and safety precautions regarding use of Atlantic Fleet Operating Areas. The area offshore North Carolina is in two different operating areas, the Virginia Capes Operating Area and the Cherry Point Operating Area (Figures 8-4 and 8-5); the controlling authority for both is the Commanding Officer, Fleet Area Control and Surveillance Facility, Virginia Beach, Va. (In addition, the airspace warning area W-177, south of Brunswick County, is under the scheduling command of the Myrtle Beach Air Force Base, Myrtle Beach, S.C.) These areas are used for a variety of purposes, including submarine and surface fleet exercises, air combat maneuvering, air-to-air gunnery, and test flights. Submerged operations may occur in any part of the operating areas, but must receive specific clearance first. Regularly used submarine transit lanes are shown in the figures; these lie seaward of all but a few of the lease blocks sold in Sale 56, but for much of their length lie within the bondaries of proposed Sale 78.

A number of steps are usually taken to identify and avoid potential conflicts between military and civilian uses of the continental shelf. Pipeline right-of-way applications submitted to MMS are circulated within the Navy and other services for review, and comments on any potential conflicts are provided to MMS. Thirty-nine of the 43 leases let off North Carolina carried a military stipulation that, among other things, committed the lessee to coordination with the military regarding both electronic communications and all boat and aircraft traffic within offshore warning areas. (The other four tracts lay within the "control area" that existed between the Virginia Capes and Cherry Point Operating Areas at the time the stipulations were written.) Information on specific military activities that might interfere with pipelaying are also published by the Coast Guard in their weekly Local Notice to Mariners and identified in the Coast Guard's marine broadcasts. In addition, a variety of safety precautions are required prior to and during any

Figure 8-4. Virginia Cape Operating Area. (Source: CINCLANTFLT INST. 3120.26B)



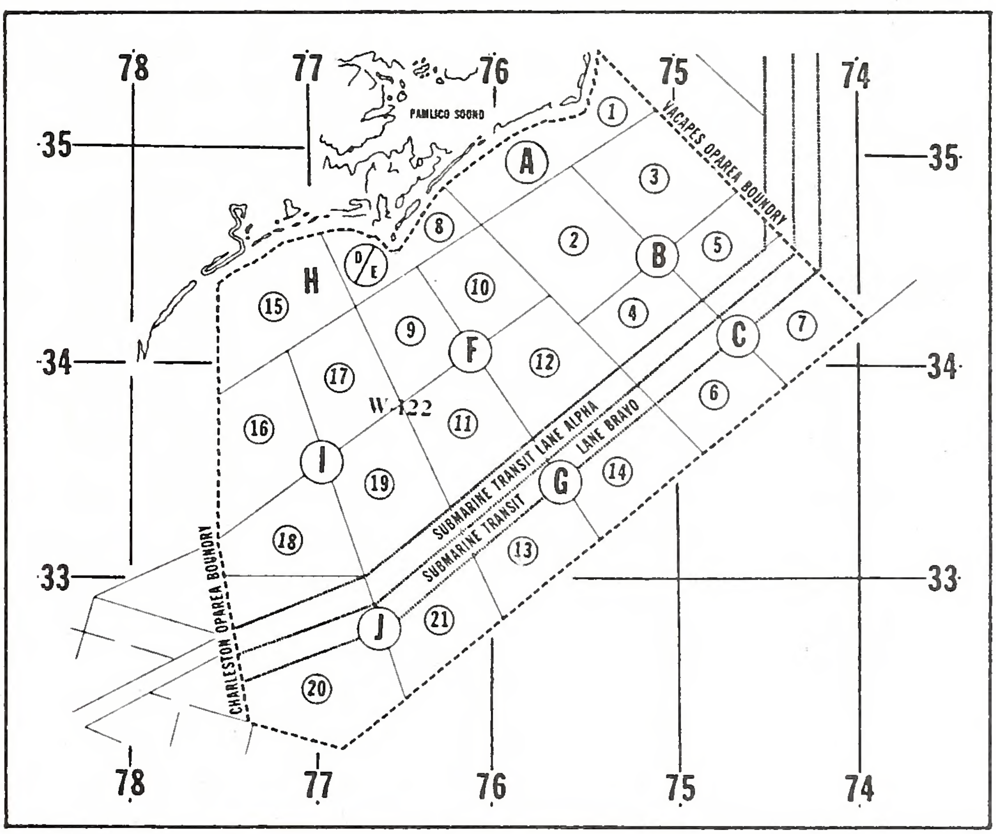


Figure 8-5. Cherry Point Operating Area. (Source: CINCLANTFLT INST. 3120.26B)

exercise to minimize the potential danger to any vessels or aircraft inadvertently in the area.

Nearshore Restricted Areas. A number of danger zones have been established for military use in the state's nearshore waters. Regulations restricting civilian entrance to and use of these areas are set forth in 33 C.F.R. §204. These danger zones include target areas, bombing and rocket firing areas, ordnance test areas, and firing ranges; they occur in Currituck, Albemarle and Pamlico Sounds, in the New River, and in the vicinity of Browns and Bear Inlets. The areas vary as to whether dummy or live munitions are used, and as to whether they are permanently closed, accessible by permission, or regularly open at certain times. The possibility of pipelaying in one of these areas will depend on its past, current, and anticipated uses, and will be handled on a case-by-case basis.

There are also two areas of restricted navigation in North Carolina waters (see 33 C.F.R. §207), in the Neuse River near Cherry Point Marine Corps Air Station, and in the Cape Fear River adjacent to Sunny Point Military Ocean Terminal. Nonmilitary ships must receive permission before entering these areas.

Onshore Installations. In North Carolina's coastal zone, there are five military installations of more than 10,000 acres each: Cherry Point Marine Corps Air Station in Craven County, Camp Lejeune Marine Corps Base in Onslow County, the Dare County Bombing Range used by the Air Force and under the control of Seymour Johnson Air Force Base in Goldsboro, Sunny Point Military Ocean Terminal in Brunswick County operated by the Army for the loading and unloading of military supplies, and Piney Island in Carteret County used by the Marine Corps for military exercises.

In addition, a number of smaller facilities owned and operated by the Navy, Marine Corps, Air Force, Army, and Coast Guard lie scattered throughout coastal North Carolina, ranging in size from a fraction of an acre to several thousand acres. These areas include outlying air fields, target areas, communication stations, lighthouses, and life boat stations, among others.

Utility easements across some of these areas have been granted. The possibility of obtaining a pipeline easement across a military area will vary, of course, from site to site, and applications will be handled on a case-by-case basis.

Unexploded Ordnance. Explosive ordnance along the eastern U.S. continental shelf can be anticipated, as military training, sea dumps, and combat operations have occurred throughout the area (Griffin, 1981). National Ocean Survey nautical charts show several sites off North Carolina where unexploded ordnance is known to have been lost, including sites off Capes Hatteras and Lookout and near the mouths of the New and Cape Fear Rivers. In addition, the area around Hatteras Inlet was mined by the U.S. during World War II, and the Chief of Naval Operations later concluded that it would be impossible to remove a large enough percentage of these mines to render the bottom safe for general use (Johnson, 1982). As a result, a semicircular area seaward of Hatteras and Ocracoke Islands, centered on Hatteras Inlet and extending from Cape Hatteras to Ocracoke village, is outlined on nautical charts and accompanied with the following note: "Area is open to unrestricted surface

navigation but all vessels are cautioned neither to anchor, dredge, trawl, lay cables, bottom, nor conduct any other similar type of operation because of residual danger from mines on the bottom." Fishermen have been trawling this area for more than 15 years, however, and it is now felt to be more or less clear (Holland, 1982).

Trawl fishermen occasionally bring up unexploded ordnance in their nets, and some have detonated. The chance exists that a pipeline route could pass over or near undetonated explosives, and this possibility, although somewhat remote, should be anticipated.

8.7 CULTURAL RESOURCES

The historic and archaeological resources of coastal North Carolina include prehistoric remains of native cultures, onshore historic structures and sites, and shipwrecks in the sounds and offshore waters. The first evidence of man in coastal North Carolina dates from roughly 8,000-10,000 B.C. Distinctively shaped spear points used to hunt large animals have been found in Pasquotank, Bertie, Tyrrell and Onslow Counties, among others. These sites were probably small hunting camps, with few artifacts left behind upon abandonment.

Between then and the arrival of Europeans, there appears to have been a gradual increase in population in the coastal plain and a shift in settlement eastward toward estuarine areas as fish and shellfish resources came to be exploited. People adopted more sedentary habits, particularly after the introduction of agriculture during the first five centuries A.D. By the time of European contact, a socially complex society had developed, based on subsistence agriculture and supplemented with hunting and fishing (Phelps, 1975). The evidence left behind of this prehistoric settlement is in the form of permanent villages, seasonal encampments, mass burials, shell middens and other features, many of which have been drowned by slowly rising sea levels over the past 10,000 years.

Following various exploratory expeditions and the failure of Sir Walter Raleigh's colony on Roanoke Island in 1584-85, the first permanent European settler arrived in North Carolina in 1653. Settlement initially occurred on the north shore of Albemarle Sound and by 1700 had spread to the Pamlico and Neuse Rivers. Colonization along the Cape Fear River began in the 1720's. Towns soon appeared: Bath, the first town in North Carolina, was chartered in 1706, and New Bern was established in 1710. By the Revolution, settlement in the state had already pushed westward to the foothills of the Blue Ridge (Powell, 1975).

With the arrival of Europeans came shipping and shipwrecks. Over 2000 vessels have been reported lost off North Carolina's coast, earning for the Outer Banks the title of "Graveyard of the Atlantic." Clusters of wrecks occur on the shoals off Capes Hatteras, Lookout and Fear, with secondary concentrations along the beaches between Tubbs Inlet and Carolina Beach, along Bogue Banks, and along the beaches north of Cape Lookout (SAI, 1981; Newton et al., 1971).

Many of these important historic and archaeological sites in North Carolina have been recognized by inclusion on the National Register of

Historic Places, maintained by the Secretary of the Interior. The Register, originally established in 1935, was expanded under the National Historic Preservation Act of 1966 to include "districts, sites, buildings, structures, and objects significant in American history, architecture, archeology, and culture" (16 U.S.C. §470a). As of February 1982, there were 159 National Register sites in the state's twenty coastal counties, and one (the remains of the Federal iron-clad gunboat Monitor) on the OCS.

Protection for historic and archaeological resources in North Carolina is derived largely from Section 106 of the National Historic Preservation Act of 1966 (16 U.S.C. §470, as amended) and Executive Order 11593 at the federal level, and from N.C. General Statute 121-12(a) at the state level. Section 106 requires that every federal agency having jurisdiction over any project undertaken, assisted, or licensed by the federal government "take into account the effect of the undertaking on any district, site, building, structure, or object that is included in or eligible for inclusion in the National Register." Executive Order 11593 (May 13, 1971) assures that sites that are unknown or have not been evaluated are not overlooked by requiring Federal agencies to identify all such sites within their project areas. As a result of FERC's Certificate of Public Convenience and Necessity, Corps of Engineers permits, and other federal licenses, these requirements will apply to most if not all of any pipeline route. Procedures for implementing these mandates (36 C.F.R. §800) require that the federal agency consult with the State Historic Preservation Officer to locate sites within the project area and to determine whether the project will have an adverse impact on these sites. If an adverse impact is foreseen, the agency must either revise the project or formally consult with the Advisory Council on Historic Preservation. The Council's recommendations, though not binding on the agency, are rarely ignored.

North Carolina General Statute 121-12(a) provides for a similar process of identification and consultation for projects undertaken, assisted or licensed by the state, with the North Carolina Historical Commission serving in a role comparable to the Advisory Council. The major difference between the North Carolina and federal legislation is that the former applies only to sites listed on the National Register, and not those eligible for it.

In addition, there are several other sources of protection for cultural resources within limited geographical areas. The Marine Protection, Research and Sanctuaries Act of 1972 (33 U.S.C. §§1401-1444; 16 U.S.C. §§1431-1434) authorizes the Secretary of Commerce to designate as marine sanctuaries areas "that are distinctive for their conservation, recreational, ecological or esthetic values." One sanctuary has been designated off North Carolina: the Monitor Marine Sanctuary, an area within a one-half mile radius of the wreckage of the federal gunboat Monitor (itself on the National Register) lying a few miles southeast of Cape Hatteras. Regulations governing activities within the sanctuary are listed at 15 C.F.R. §924; they would effectively exclude pipelaying activities within the sanctuary.

Regulations adopted pursuant to the North Carolina Coastal Area Management Act (15 N.C.A.C. 7H .0500) provide for the designation of Areas of Environmental Concern (AECs) in two relevant categories: Significant Coastal Archaeological Resources and Significant Coastal Historic Architectural Resources. Sites so designated would receive the benefit of the major development review required under CAMA for pipelaying activities. At the

present time, however, no AECs in these two categories have been designated. In addition, use standards established for many of the other AEC categories require that "development shall not cause major or irreversible damage to valuable documented historic architectural or archaeological resources" (15 N.C.A.C. 7H .0200-.0300).

Stipulation No. 1, attached to all Sale 56 leases, requires lessees to conduct cultural resource surveys and take appropriate mitigation measures as directed by MMS. The stipulation will have minimal impact on pipelaying, however, for not only does it apply only to the lease tracts themselves, but also none of the tracts leased off North Carolina fall within the "cultural resource sensitivity line" established by MMS as the main criterion for invoking the terms of this stipulation. Cultural resource survey requirements for OCS pipelines are set by MMS under the general authority of Section 106 and will be discussed shortly.

Finally, the National Environmental Protection Act and the State Environmental Protection Act require that federal and state agencies, respectively, consider the environmental consequences of their actions; environmental consequences are taken to include impacts on cultural resources as well.

The impact of pipelaying activities on North Carolina historic and archaeological resources is apt to be small, provided current regulatory protection continues. Pipeline construction through a site could, of course, damage or destroy its historical or archaeological value. If a site is on or eligible for the National Register, however, consultation under Section 106 or G.S. 121-12(a) would first be required. Because of the time and costs involved in complying with these procedures, pipeline companies are generally anxious to avoid such sites. Officials at FERC and the N.C. Department of Cultural Affairs noted that the vast majority of potential conflicts are settled before they get to the Advisory Council or Historical Commission (Hoffman, 1981; Hall, 1981). In most cases, the pipeline is simply rerouted.

Where historic and archaeological sites have already been identified, avoidance is fairly easy. A simple check of the National Register and its pending and nominated files will identify potential conflicts early in the planning process. Most of these sites are less than several acres in extent and easily avoided. A few are relatively large: historic districts (of which there are eleven in the twenty coastal counties) may contain a number of city blocks, and one plantation site includes some 500 acres of surrounding land. Nonetheless, early planning should permit conflicts to be minimized or avoided altogether.

Greater difficulty arises in areas where cultural resources may exist but have not yet been found or documented. The normal procedure is for the federal agency, in consultation with the SHPO, to require the applicant to undertake surveys to locate sites eligible for the National Register. Such surveys typically begin with a literature and records search involving maps, published data, local historic sites lists, archaeological site files of pertinent institutions, and other sources. For areas that have not been adequately surveyed, a field survey will also be required. Onshore, this usually involves a complete survey of structures within the project area, and a ground survey (with occasional subsurface testing) of the entire route or of only those

portions deemed to have a high probability of containing cultural remains (Garrow and Bernhardt, 1980; Hall, 1981). Such surveys will usually identify most of the significant cultural resources within the project area, substantially reducing the chances either that a site will be discovered during construction, causing costly delays, or that a site will be accidentally destroyed.

If a site is found, it must be evaluated in terms of criteria for nomination to the National Register. If the site fails to meet those criteria, then no further investigation or preservation of the site is mandatory, and construction may proceed. Should the site fulfill National Register criteria, however, two options are available. The most common alternative is to avoid the site. This will involve some re-engineering (and of course survey of a new corridor), but is often more cost- and time-effective than the alternative, which is to carefully excavate and preserve that portion of the site to be disturbed by construction (Garrow and Bernhardt, 1980).

Offshore cultural resources in North Carolina include shipwrecks and prehistoric sites occupied when the shelf was dry land, though occurrence of the latter is only a strong presumption, as no direct evidence of prehistoric occupation of the shelf has been reported (SAI, 1981). These resources could be affected by pipelaying operations in several ways: placing the pipeline on the ocean floor may crush the fragile wood remains of historic ships; bottom disturbance by anchors or pipeline burial could physically damage artifacts, move them out of sequence or lift them from their protective mud or sand cover, exposing them to current action; and the placement of a pipeline in the vicinity of a shipwreck could preclude the latter's discovery by masking the magnetic signature of the wreck on a magnetometer with the much larger anomaly of the pipeline (USDOI/BLM, 1981d).

As onshore, known offshore cultural resources will be fairly easy to avoid. However, the task of locating undiscovered resources is complicated by several factors. One is that, regarding prehistoric sites, no one is even sure where to look. The area in which these sites might be found is limited by both 1) the location of the shoreline when man first entered the area (seaward of which no prehistoric occupation would be expected), and 2) the degree to which the subaerial surface was eroded and destroyed during shoreline retreat. At present both of these factors are only vaguely known (ICA, 1979; SAI, 1981).

Of greater import for assessing pipelaying impact is the fact that many underwater cultural resources may not be detected by the technology currently used for pipeline route surveys. Standard procedures for archaeological surveys in the Gulf (see USDOI/BLM, 1981a) are the same as those for geophysical surveys of proposed pipeline routes; they require deployment of a magnetometer, dual side-scan sonar, depth sounder and subbottom profiler on three survey lines, one following the proposed pipeline route, and one offset to either side to coincide with the area that would be disturbed by barge anchors. Prehistoric artifacts for the most part cannot be detected by these systems (or any others available), although large features, such as submerged shell middens, could be imaged by side-scan sonar and subbottom profiler systems (SAI, 1981). Shipwrecks are easier to detect, particularly if they contain enough ferrous material to be visible to a magnetometer, or if they project from the bottom sufficiently to be detected by side-scan sonar or depth recorders. A detailed review and evaluation of the equipment and

procedures used to detect and recover underwater cultural resources is presented in ICA (1979).

If an unidentifiable anomaly is found in the data within the cultural resource sensitivity line, current MMS procedure in the Gulf requires that efforts be made to avoid bottom disturbance near the site unless it can be demonstrated that the anomaly is of no cultural significance (USDOI/BLM, 1981d).

Sources: Publications indicating the location of cultural resources include the National Register (most recently updated at 47 Federal Register 4932 ff., Feb. 2, 1982), National Ocean Survey nautical charts (shipwrecks), and the Oceanographic Atlas of the Carolina Continental Margin by Newton et al. (1971) (locations of ships reported lost). More recent, precise, and complete information can be obtained from the appropriate branches of the N.C. Department of Cultural Resources, Division of Archives and History: the Survey Branch (for historic structures) and Archaeology Branch (for land archaeology), both in Raleigh, and the Underwater Archaeology Branch (for shipwrecks and other submerged sites) at Fort Fisher.

8.8 ROADS, RAILROADS AND PUBLIC UTILITIES

Crossings of roads, railroads, telephone and power lines, and water, sewer, and gas pipelines are almost inevitable during onshore pipeline construction. Underwater utility lines may also lie across the pipeline route. While construction will create some inconvenience for utility owners and users, procedures have been developed over the years to minimize service disruptions. With careful planning and adequate care during construction, serious inconvenience to users of these systems can be avoided.

The paralleling or use of existing rights-of-way during pipeline construction entails a number of separate concerns, and these will be discussed in the section on use of existing rights-of-way (Section 9.3). Only utility crossings by pipelines will be discussed here.

8.8.1 Roads and Railroads

The methods used for pipeline construction across roads and railroads were discussed in Chapter III. Lightly travelled roads may be open-cut, depending on such factors as traffic volume, availability of a detour, road class, and requirements of the highway agency (Golden et al., 1980). For state-maintained roads in North Carolina, the policy of the state's Department of Transportation (NCDOT) is that secondary roads with an average daily traffic volume of less than 2000 and unpaved roads may be open-cut at the discretion of the Division Engineer. Where open cuts are made, there will be a short-term disruption of traffic for one to several days. The effects of open cutting can be reduced in three ways: by placing steel plates over the trench at the end of the working day to permit normal traffic flow during non-working hours, by scheduling construction, where possible, to avoid the days and hours of peak use, and by cutting only a portion of the roadway at one time, allowing traffic to continue over the uncut (or restored) portion. NCDOT policy for state roads, for instance, requires that the trench within the travelled portion of the roadway be covered at night except in emergencies, and that no more than half the roadway width be cut at one time

so that traffic can be maintained. Requirements for cutting county or municipal roads may differ, of course.

More heavily travelled roads and railroads generally are not permitted to be open cut, and the pipeline is installed by boring or tunneling underneath the roadway, a procedure that does not interfere with surface traffic. During boring operations there may be some traffic interference and delays as a result of slow-moving vehicles entering, using, or leaving the roadway, and the presence of vehicles and construction activity on the road shoulders and slopes may present a minor safety hazard, but these problems will be minimal provided adequate precautions are taken.

Some aspects of the design and location of pipeline crossings will have a bearing on roadway operation and safety. For various reasons, certain locations are generally considered undesirable for pipeline crossings: these include locations near footings of structures; at cross drains where the flow of water, drift, or stream bedload may be obstructed; and for liquid pipelines, underpasses drained by pumps. The external load exerted on the pipeline by road and railroad traffic is an important factor in crossing design. Traditional practice has been to install a separate casing pipe under the roadbed, within which the line pipe is held in place by spacers or insulators. From an engineering point of view, however, uncased pipelines, sometimes with extra wall thickness, provide better solutions to load problems (Petroleum Extension Service, 1973). Casing requirements vary among jurisdictions, but many agencies permit uncased pipelines provided certain conditions or standards are met. Burial depth can also be important in eliminating potential interference between road and pipeline systems. The U.S. Department of Transportation requires gas and petroleum pipelines to be installed a minimum of 3 feet below road and railroad drainage ditches (49 C.F.R. §§192, 195), and the NCDOT requires these lines to be buried at least 3 feet below the travel surface of state roadways.

An additional impact of pipeline construction on road systems will be the temporary use of roads providing access to the site by construction equipment and other vehicles, particularly pipe-hauling trucks. This will cause a slight increase in congestion, roadway wear, and traffic hazard.

8.8.2 Pipelines and Buried Cables

Current practice for crossing pipelines and buried cables varies depending on the environment. Offshore, the standard practice for pipeline crossings is to lower the existing pipeline to provide ample clearance between it and the newly laid line. Sacks filled with sand or cement are placed over the existing line to maintain a stable clearance (Golden et al., 1980). Since cables, on the other hand, must be available for reservicing at the surface, pipelines are installed and buried beneath existing cables.

The minimum allowable clearance is established by federal regulation. U.S. Department of Transportation regulations (49 C.F.R. §§192.325 and 195.250) require a minimum of 12 inches of clearance between a buried pipeline and any other underground structure, though a smaller clearance may be permitted if additional protection is provided. MMS policy in the Gulf is somewhat stricter, requiring an 18-inch minimum separation between pipelines (USDOI/BLM, 1981a).

Currently, the only offshore pipelines in North Carolina are the pair of mammoth (13-ft. inside diameter) concrete cooling-water discharge pipes of CP&L's Brunswick Nuclear Power Station that extend 2000 feet offshore from Caswell Beach. A pipeline crossing of these lines would be very difficult, but the lines are short enough to be easily avoidable. There are also a number of existing pipeline river crossings. At Wilmington, for instance, these include an array of small-diameter petroleum products lines owned by Exxon Pipeline Co., a pair of N.C. Natural Gas Corp. lines, and two 24-inch and several smaller city water lines; crossings also occur at Fayetteville, at several points along the Intracoastal Waterway, and at other coastal plain locations. As these lines run perpendicular to the river or channel, rather than parallel to it, it is unlikely that they would be crossed by another pipeline.

A number of communication and power cables also lie underwater in coastal North Carolina. Because no trans-Atlantic cables originate in the state, the shelf seaward of the barrier islands is cable-free. But telephone and electric cables cross many of the sounds and smaller waterways. In some cases, their alignment is parallel to the coast, so crossings may be necessary. Underwater cables are shown on nautical charts, and no serious problems in crossing them are anticipated.

Onshore, underground utility lines include water, sewer and gas pipelines and telephone and power lines. The standard practice here is to place the pipeline underneath the existing line. This is commonly done also in marsh areas, where a suction dredge and divers may be needed to place the new line below an existing pipeline (Petroleum Extension Service, 1973). USDOT regulations governing minimum clearance between pipelines and other structures apply in these environments as well. Special precautions are necessary in crossing major or hazardous utility lines, but in general the impacts of pipeline construction on buried utility systems will be minor, if they occur at all.

8.8.3 Overhead Lines

Overhead power and telephone lines will present very little problem for pipeline construction. Where poles must be moved, or the lines are low enough to interfere with equipment, some means will be needed by which utility service can bypass the construction site. Service interruptions are not expected, and utility companies are committed to preventing them. Crossings under high voltage lines also present hazards for pipeline construction workers, and certain precautions will be necessary. During construction of a 6-inch line under 765,000 volt transmission lines in Illinois, for instance, pipes were checked three times daily for excess voltage, and vehicles were grounded by dragging lengths of steel chain (Watts, 1981).

Sources. Approximate locations of underwater pipelines and cables are indicated on National Ocean Survey nautical charts. The most accurate information for route planning purposes will be system maps compiled by the various departments and utilities. Jurisdictions within the coastal area include: 1) for roads, highway departments at all levels (federal, state, county, and municipal); 2) railroads include the Seaboard Coast Line, Norfolk Southern, Atlantic & East Carolina, Beaufort-Morehead, and Camp Lejeune lines; 3) pipelines are operated by the N.C. Natural Gas Corp. and various municipal

gas companies, municipal (and occasional regional) water and sewer departments, and a few industrial concerns (e.g., Exxon and Texasgulf); 4) Carolina Telephone serves most of the coastal area, while smaller portions are serviced by Southern Bell, the Atlantic and Tri-County Telephone Membership Corporations, and Continental Telephone Co. of Virginia; and 5) electric utilities include Carolina Power and Light, Virginia Electric Power, and various electric membership cooperatives and municipal companies.

8.9 LAND USE

Pipelines do not require a large amount of land in any given area. The width of the right-of-way varies with a number of factors, as discussed in Chapter III, but in general, rights-of-way for large diameter pipelines may run 100 ft. for construction and repair activities and 40 ft. for normal operation. These figures correspond to 12.1 and 4.8 acres/mile, respectively. More land is typically needed during construction at river, road and railroad crossings, and for ancillary facilities such as access and service roads, valve, compressor and pump stations, tank farms, and gas plants. Several of the latter are discussed in Section 9.2.

In general, the right-of-way instrument provides that temporary working space used during construction, most of which is adjacent to the permanent right-of-way, reverts back to the landowner upon completion of the line. This portion of the construction right-of-way is then available for resumption of its preconstruction land use. Within the permanent right-of-way, on the other hand, certain land uses that pose a potential hazard to the pipeline or that impede maintenance and repair activities are not allowed. These include excavation, the erection of permanent structures, and the growth of trees.

The land use impacts of pipelines, then, can be divided into two periods of time:

1) During construction, all land uses are preempted within the construction right-of-way.

2) During operation, restrictions on use of the permanent right-of-way preempt certain land uses (such as forestry and urban uses) for the life of the pipeline. Other productive land uses are generally permitted to continue. To minimize the impact of these restrictions, it is common practice (at least with some companies) to route the pipeline near property boundaries so as to least encumber use of the property by the landowner.

It would be impossible to discuss the impacts of pipeline construction and operation on all land uses in eastern North Carolina, but three land use categories are sufficiently common and raise sufficient concern to merit discussion. These are urban areas, agriculture, and forestry.

8.9.1 Urban Land Use

Two general types of urban land use occur in eastern North Carolina. Intensive vacation home and resort development can be found in long, linear patterns, most commonly on barrier islands but also along the shores of some sounds and rivers. More traditional urban centers occur scattered throughout the coastal zone, for the most part adjacent to navigable rivers and channels. None are large by current standards, the largest being Wilmington with a 1980

population of 44,000. Other major towns include Jacksonville, New Bern, Washington, and Elizabeth City.

Urban areas are preferably avoided by pipeline companies for several reasons. Construction through such areas can be extremely slow because of existing structures and utilities that must be crossed, traffic that must be rerouted or accommodated, and a working area that is severely restricted. A recent 12-mile stretch of 36" gas pipeline built through Los Angeles, for instance, required twelve months to complete (Pipeline and Gas Journal, 1981). Maintenance and repair activities are also difficult and slow for the same reasons. The greater level of building activity in urban areas creates a greater potential for accidental pipeline damage. High population density also means that more people will be endangered by a pipeline leak or rupture. Finally, the typically fractured ownership patterns of urban areas make right-of-way acquisition difficult and time consuming.

Where pipelines are built through urban or urbanizing areas, the primary impacts of construction will be the disruption, inconvenience and annoyance caused to commuters, residents and workers. There will also be potential for accidental rupture of utility lines due to inaccurate maps or careless work, and for accidents associated with construction activities (particularly the open trench). These impacts will be relatively short-lived, however, lasting only one to several weeks in any one location.

During operation, the presence of the pipeline may have several effects on nearby land use patterns. Since use of the right-of-way will be restricted to activities compatible with pipeline operation, maintenance, and safety, the pipeline will act to some extent as an encumbrance on urban expansion. This effect will be most acute in industrial areas and in other situations (commercial centers, apartment complexes) where large blocks of land must be assembled for development. In residential neighborhoods, the hazard created by a pipeline's presence may depress nearby property values. On the other hand, a pipeline right-of-way through a residential area could be developed as a linear park or greenbelt, adding to the quality of life and increasing property values (USDOI, 1976). We are unaware of any studies conducted to measure such effects.

The hazard created by the presence of high pressure gas lines is significantly greater in densely populated areas merely by virtue of the greater number of people in the pipeline's vicinity. (The question of pipeline safety per se is explored in Section 9.1.) To partially reduce this greater degree of hazard in urban areas, the U.S. Department of Transportation (DOT) has promulgated regulations establishing four pipeline location classes that are defined in terms of population density within one-eighth mile of the pipeline (49 C.F.R. §192). Safety design requirements in both DOT regulations and industry standards are specified in terms of these location classes. The DOT regulations, for instance, require lower pipe operating pressures (or stronger pipe), shorter distances between main line block valves, and greater depths of soil cover for gas lines in more densely populated areas.

A common problem arises when urban development increases the class location of a particular pipeline segment. DOT regulations require the pipeline's operator to monitor population changes near its line and to undertake a formal study if population increases indicate that a change in the

pipeline's class location has occurred. If class location has changed and the original tests do not indicate whether the pipeline section meets the new class location standards, the operator must retest that section of line. If it meets the more stringent requirements of the new class location, no further action is required. If it does not, the operator has two options: to reduce the maximum allowable operating pressure, thereby reducing throughput capacity, or to install replacement pipe, either within the existing right-of-way or in a new right-of-way (Golden et al., 1980). Because of the problems and expense of both options, it is common for pipeline companies to install pipelines in developing areas to meet the standards of the expected future class location.

Class locations have only been established for gas pipelines and not for oil lines. However, DOT regulations do require additional soil cover for oil lines in industrial, commercial, or residential areas (49 C.F.R. §195.248).

8.9.2 Agriculture

The 1978 Census of Agriculture recorded over 8,000 farms covering 1.5 million acres in the twenty-county coastal area of North Carolina (Table 8-9).

Table 8-9. Farm statistics for eastern North Carolina, 1978

County	No. of Farms	Acres in Farms	Percent of County Land Area	Total Cash Receipts From Farm Marketings ($1000's)
Beaufort	1047	169,958	32.2	50,801
Bertie	950	183,987	41.2	48,120
Brunswick	671	67,368	12.3	24,613
Camden	166	55,480	36.3	11,708
Carteret	183	68,663	20.0	6,396
Chowan	312	57,502	51.9	16,368
Craven	701	106,664	23.8	37,396
Currituck	147	58,542	37.2	9,288
Dare	5	N/A	0.6	220
Gates	386	73,861	34.2	19,127
Hertford	437	98,620	43.7	23,859
Hyde	213	92,881	23.7	12,317
New Hanover	83	12,943	10.9	1,984
Onslow	740	85,419	17.4	22,064
Pamlico	174	42,597	19.7	10,162
Pasquotank	290	67,417	46.2	17,444
Pender	652	98,323	17.6	25,203
Perquimans	397	83,667	53.1	18,989
Tyrrell	173	56,492	22.6	8,529
Washington	385	110,699	50.4	26,284
Total	8112	1,591,083		390,872

Sources: Columns 1-3 from USDOC/BC, 1981; Column 4 from N.C. Crop and Livestock Reporting Service, 1980.

Over 80% of these farms were owner-operated. State records for that year show that total farm marketings for those counties amounted to slightly more than $390 million, roughly 12.1% of the state total.

There is wide variation in the size and type of farm operations in these counties. Large farms or "superfarms" of several thousand acres or more are common in the northeastern counties, on the peninsula between Albemarle and Pamlico Sounds, and in Beaufort County. On the other end of the scale, many farms are small family operations of only a few tens of acres. The leading crops in 1980, in terms of income, were tobacco, corn and soybeans, while peanuts, wheat and Irish potatoes also produced significant harvests (N.C. Crop and Livestock Reporting Service, 1981).

Where the pipeline route crosses agricultural lands, most of the impacts of construction will be only temporary in nature. The right-of-way is almost always allowed to revert to agricultural use following construction, and no long-term changes in land use are expected except where aboveground facilities are required.

The most immediate impact will be the loss of crops or pasture within the construction right-of-way during the year of installation. Figures in Table 8-10 provide some rough estimates of the economic losses entailed in this lost production. Since the time during which the right-of-way will be used for construction may be only a few days or weeks, depending on the timing it may be possible to raise some crops, such as early maturing varieties that could be harvested before fall construction, or winter grains before summer installation. Adequate advance planning is necessary if such timing is to be successful. More permanent crop losses will occur where the right-of-way traverses orchards. All trees within the construction right-of-way will be removed, and while the area outside of the permanent right-of-way can be

Table 8-10. Selected statistics on cropland value and production in North Carolina, 1979-1981.

	1979	1980	1981
Rent per acre, cropland rented for cash, N.C. average	$ 37.10	$ 38.40	$ 44.40
Average gross farm income per acre, N.C. average	325.53	N/A	N/A
Average net farm income per acre, N.C. average	88.60	N/A	N/A
Average value of corn harvested per acre, N.C. coastal plain	218.99	229.46	N/A
Average value of soybeans harvested per acre, N.C. coastal plain	153.05	155.26	N/A

Source: N.C. Crop and Livestock Reporting Service, 1980, 1981.

replanted following construction, it will be several years before the trees bear fruit, and probably several more before they are as productive as the ones they replaced. The crop from trees within the permanent right-of-way will be lost for the life of the pipeline.

Pipeline construction will also cause a temporary decline in soil productivity as a result of soil compaction, erosion, and the mixing of subsoil with topsoil. These problems were discussed earlier in Section 7.11. The degree and duration of productivity loss will depend on soil type and condition and on the construction and restoration methods used, and is difficult to predict in advance. Several measures are available to reduce the severity of impact. These include avoidance of soils during wet periods, the use of balloon tires and tracked vehicles to minimize compaction, double-ditching, the removal of surplus subsoil from the site, the use of disking, harrowing, and other cultural measures to leave the soil in good condition following construction, and the immediate fertilization and seeding of the right-of-way to minimize erosion and improve soil structure.

Pipeline construction may also disrupt normal farming operation and create inconvenience for the farmer. The movement of farm machinery and tillage or harvesting operations may be complicated by construction activities, livestock movements may be prevented or made more difficult, portions of fields may become temporarily isolated, and noise and air pollution may affect production of farm animals (USDOI, 1976). The disruption of drainage systems and its potential consequences were discussed earlier in the section on soils.

Pipeline companies have been criticized by farmers' groups in the past for preferring agricultural fields to other land uses for pipeline routes. Cropland has obvious advantages for pipeline operators, as the costs of both land clearing and right-of-way maintenance are eliminated. This may be a sore point in North Carolina as well, and there is no obvious and equitable solution. One reasonable solution might be for the pipeline company to share some of the cost savings with the farmer.

More generally, the state can help to reduce the economic impact on farmers by making information and expertise available to them regarding the right-of-way agreement and the various mitigation measures that can be written into it. Such a program could be conducted by the Agricultural Extension Service.

Good communication with farmers and attention to farmers' concerns will benefit the pipeline company in terms of smoother right-of-way negotiations and better cooperation during construction and operation. An example of how this can be done is the use of "Farmer Liaison Officers" by British Gas during construction of its 36-inch gas pipeline in Scotland. These employees visited all land occupiers prior to construction to learn their individual requirements, such as:

1) the type of temporary working fence to be constructed around the construction site (e.g., stockproof; deer fencing; rabbit netting);
2) access requirements of the farmer across the working width;
3) the method to be used for reinstating the land drains; and
4) any other special requirements, restrictions or qualifications. (Barbeary, 1977)

For the most part, the impacts of pipelaying on agricultural lands will be temporary. Most of these impacts can be anticipated beforehand and dealt with either through compensation (for the loss of crops, etc.) or mitigation (e.g., double-ditching). No large-scale siting concerns are evident.

8.9.3 Forestry

In 1980, forestry accounted for an estimated $85 million in net income to land owners in the twenty coastal counties, while the total value of the industry greatly exceeded this by the value added in harvesting and processing the wood products (Forest Resources Extension Office, 1981). Acreage data from the last comprehensive survey of the state's forest resources, conducted in 1972-1973, is presented in Table 8-11.

Pines, particularly loblolly, dominate the forest harvest of eastern North Carolina, though a variety of hardwoods (oaks, sweetgum and others) contribute a share. In recent years, roughly 70% of this harvest has come from small, private woodlots and 30% from forest industry lands. The latter include substantial holdings by several major forest products companies, including Weyerhauser, Champion International, Federal Paper, and Georgia Pacific. Two trends in forestry practices have been evident in the last decade: the conversion of forest land to agriculture, especially on the relatively unproductive pocosin soils, and improvements in forest management, particularly more intensive management of industry lands, accompanied by improved drainage and conversion to loblolly pine monoculture (Hamilton and Harkins, 1981).

There are two major impacts of pipeline construction on commercial forest land:

1) Loss of timber within the construction right-of-way. During construction, all trees within the construction right-of-way are removed, regardless of maturity. In many cases, the trees will have some salvage value, but except where the right-of-way passes through a fully mature stand that would otherwise be clearcut, the landowner will suffer some economic loss.

2) Loss of forest productivity in the permanent right-of-way. Since trees are prevented from growing within the permanent right-of-way during the

Table 8-11. Acreages of Different Ownership Classes of Forest Land in the Twenty Coastal Counties of North Carolina, 1972. (from Cost, 1974, and Welch and Knight, 1974)

	acreage	as % of commercial forest land total
Total land area	5,993,792	
Commercial forest land, all ownerships	4,114,399	100%
Public	366,987	9%
Forest Industry	1,216,488	29%
Farm	1,101,019	27%
Miscellaneous private	1,429,905	35%

lifetime of the pipeline, the landowner will lose the income potential of the land for that period.

Assuming a construction right-of-way width of 100 feet and a permanent right-of-way width of 40 feet, the area affected by these impacts will be 12.1 and 4.8 acres/mile, respectively. For the landowner, both of these concerns are primarily economic matters that can be resolved by appropriate compensation.

In addition, several other impacts may occur that usually are of only occasional or very local concern. These include: the temporary disruption of forest operations; the forest fire hazard created by pipelaying during dry periods (forest officials may shut down operations at particularly hazardous times) (USDOI, 1976); the disruption of drainage patterns; changes in soil fertility from compaction and the mixing of subsoil with topsoil; the aesthetic impact of long corridors cleared through timberland; and potential changes in wildlife habitat. The latter four are discussed more fully elsewhere in this report.

8.10 PARKS AND RECREATION

Coastal North Carolina is one of the most popular and heavily used vacation areas on the East Coast. Popular activities include swimming, sunbathing, fishing, hunting, boating, waterskiing, surfing, and beachcombing, and visitors engage in at least some of these activities during every month of the year. Both public agencies (state and national parks and forests and county and municipal parks) and private firms and organizations (marinas, fishing piers and hunting clubs) help meet this recreational demand. In 1980, travel and tourism expenditures in the twenty coastal counties totalled over $355 million, and three of these counties (New Hanover, Carteret and Dare) ranked in the top ten in the state (Rulison, 1981).

Two units of the National Park Service comprise the majority of public park acreage in coastal North Carolina (Table 8-12). Cape Hatteras National Seashore is a well-established and developed park, accessible by road and car ferries, that received over 2 million visitors in 1978. In contrast, Cape Lookout National Seashore to the south, a more natural park without vehicular access, had 51,000 visitors that year (USDOI/NPS, 1980, 1981).

Other public parks in coastal North Carolina include three smaller National Park Service units, eight state parks, and a host of county and municipal park areas. Other public agencies provide recreational opportunities in areas they own or manage in conjunction with their other responsibilities. These areas include Croatan National Forest (U.S. Forest Service), National Wildlife Refuges (U.S. Fish and Wildlife Service), the Intracoastal Waterway (Corps of Engineers), and the Game Lands and boat ramps of the N.C. Wildlife Resources Commission.

Marinas, fishing piers, golf courses, hunting clubs, and other businesses and private organizations provide popular recreational activities. A substantial part of coastal recreation takes place in developed ocean-front areas, where second homes, motels, and campgrounds support a large vacation population.

Table 8-12. National Parks and North Carolina State Parks in the Twenty Coastal Counties.

Parks	Acreage
National Park System	
Cape Hatteras National Seashore	19,336
Cape Lookout National Seashore	24,224
Fort Raleigh National Historic Site	18
Moore's Creek National Military Park	42
Wright Brothers National Memorial	324
State Park System	
Carolina Beach State Park	1,740
Fort Macon State Historic Park and Recreation Area	385
Goose Creek State Park	1,208
Hammocks Beach State Park	892
Jockey's Ridge State Park	270
Merchant's Millpond State Park	1,947
Pettigrew State Park	768
Theodore Roosevelt Natural Area	265

Sources: USDOC/NOAA, 1978; N.C. Dept. Nat. Res. Comm. Dev., 1979.

Several statutory controls specifically relating to park and recreation areas will influence pipeline siting and construction in eastern North Carolina, in addition to the standard procedures necessary for crossing public and private lands. These include:

1) Rights-of-way through National Park Service lands must be obtained from the Director of the Park Service, and regulations governing application procedures and conditions to be met are listed at 36 C.F.R. §14. A special exception to these rules is a 500-foot wide easement across Core Banks that was reserved by the State of North Carolina when the rest of the island was deeded to the Park Service, as a possible location for a pipeline to service an offshore deepwater oil port.

2) Legislation establishing the Land and Water Conservation Fund (16 U.S.C. §§4601-4 to 4601-11) states that lands purchased with money from the Fund cannot be used for other than outdoor recreation purposes without the approval of the Secretary of the Interior. Approximately half of the state's coastal parks were purchased with LWCF monies (Hazard, 1981).

3) Part or all of the eight state coastal parks are included in the State Nature and Historic Preserve, discussed in the section on Outstanding Natural Areas. The granting of a pipeline right-of-way through these lands would require authorization by a vote of three-fifths of each house of the state legislature.

The particular impacts of pipeline construction on recreational facilities and activities are apt to be highly site specific and will depend on the character and configuration of the site, the construction methods used, the time of year, and other factors. Although it is difficult to generalize, the types of impacts that may occur can be divided into four broad categories:

1) Direct disruption or displacement of recreational activities. Beach landfall construction will remove part of the beach from use by bathers temporarily. Pipelaying activities offshore may displace boating and recreational fishing. Noise and air pollution generated by pipelaying onshore will degrade the experiences of some recreationists and reduce the success of nearby hunters and fishermen.

2) Reduced access. Pipeline construction may result in the temporary closing of roads and trails, thereby reducing access to portions of a park or recreation area.

3) Accidents. Pipeline construction activities in heavily used recreation areas present a number of safety hazards, including open trenches and the operation of large vehicles.

4) Degradation or destruction of the resource base. The most serious and long-term impacts will occur where pipelaying degrades the resource base of the recreational activity. Scenic resources are particularly vulnerable, especially in areas of mature forest where the visual scar will persist for decades. Pipeline construction may destabilize dunes, cause siltation of streams, or accidentally drain small wetlands, all of which may reduce the recreational value of an area. The presence of a pipeline may also foreclose on some options for future recreational development, such as the construction of buildings or marinas in the right-of-way.

There are, however, a number of steps that can be taken to minimize construction impacts. The most effective is relocation of the pipeline route, particularly to avoid resources that are either sensitive and slow to recover (such as visually important forested landscapes) or that are in heavy and constant use (playgrounds, marinas, etc.).

Where relocation is not possible, timing can be effective if the resource is used seasonally and can be restored within a few months. The 1967 landfall installation of a 26-inch gas line at Long Beach, Long Island, a heavily used recreational beach, was scheduled for September and October to avoid the peak summer season (Gowen and Goetz, 1981). Restoration was completed in time for recreational use the following summer. The recent construction of a 20-inch gas line across Padre Island National Seashore in Texas was halted during holiday weekends to reduce conflicts with beach users (Valley Pipe Lines Offshore Division, 1980).

Construction methods and operations also can be adjusted to minimize potential impacts. In Georgia in 1978, for instance, Colonial Pipeline Co. constructed a 40-inch line across the Atlanta Country Club golf course where the Atlanta Classic is held each year. In digging the trench, the turf was carefully cut and stacked, as was the topsoil, for later replacement. Putting greens were not cut, but rather, bored under (Ives, 1979). Special measures can also be taken to minimize disruption, hazards, or resource damage. Plans should be made well in advance for diverting recreational traffic to suitable nearby areas, and for fencing off construction areas and restricting public access. Sensitive nearby areas should be protected; during the 1973 construction of a 32-inch oil line landfall at Cruden Bay, Scotland, excavated sand was temporarily stabilized to prevent it from blowing onto an adjacent golf course (Gowen and Goetz, 1981).

Finally, prompt restoration of the right-of-way should be undertaken to provide, as nearly as possible, the same recreational opportunities as were present before construction. Restoration should include the rebuilding of road systems, replacement of facilities, and re-establishement of vegetation, particularly to screen the right-of-way (USDOI, 1976).

Sources: Information for National Park Service areas in North Carolina may be obtained from park headquarters in Manteo and Beaufort, and for state parks from the Division of Parks and Recreation in Raleigh. The most comprehensive source of information on outdoor recreation in the state is the North Carolina Outdoor Recreation Areas Inventory, maintained by the Division of Parks and Recreation. Updated on a five-year cycle, the inventory lists virtually all outdoor recreation facilities (campgrounds, playfields, marinas, boat ramps, etc.) in the state, in both public and private ownership.

8.11 WILDLIFE REFUGES AND GAME LANDS

There are two major programs responsible for managing land for wildlife protection and production in coastal North Carolina. The U.S. Fish and Wildlife Service operates seven National Wildlife Refuges in the state's coastal zone, totalling some 126,700 acres (Table 8-13). The primary emphasis at six of these refuges is on wintering waterfowl. At Mattamuskeet National Wildlife Refuge, for instance, an estimated 20,000 whistling swans overwinter, roughly one fifth of the North American population, in addition to tens of thousands of ducks of more than a dozen species, and large numbers of Canada geese (Riley and Riley, 1979). The seventh refuge, Great Dismal Swamp NWR, is a vast tract of swampland, mostly in Virgina, which provides habitat for a diverse bird and mammal fauna and several threatened or endangered species. In addition to these seven, a national wildlife refuge has been proposed for the Currituck Outer Banks. The 15,880-acre refuge would encompass all lands from the village of Corolla north to the Virginia state line, and all wetlands (on the sound side of the island) south of the village to the Dare County line. Major emphasis would be on preservation and management of these lands and adjacent waters for the large numbers of waterfowl that winter in Currituck Sound (USDOI/FWS, 1981). As of December, 1981, the proposal had been approved by the Fish and Wildlife Service and was under review by the Assistant Secretary of the Interior.

As explained in Chapter IV, pipeline rights-of-way in national wildlife refuges may be granted under the Mineral Leasing Act of 1920, but must also meet specific requirements set forth at 50 C.F.R. §29. These require that, before a right-of-way may be granted, the Fish and Wildlife Service must determine that construction is compatible with (i.e. not interfering with or detracting from) the purposes for which the refuge was established.

The main function of the Game Lands Program, operated by the North Carolina Wildlife Resources Commission (WRC), is to open up land for public hunting. In the twenty coastal counties, over 540,000 acres in more than 25 separate units were designated game lands in 1981-82 (NCWRC, 1981; the total includes portions of three units that straddled the coastal zone boundary). Some of these lands are owned by the Wildlife Resources Commission, but the majority have been added to the program through leases or cooperative agreements with private corporations and other public agencies, particularly

Table 8-13. National Wildlife Refuges in Coastal North Carolina.

Refuge	Acreage
Cedar Island National Wildlife Refuge	12,526
Dismal Swamp National Wildlife Refuge	22,000
Mackay Island National Wildlife Refuge	5,670
Mattamuskeet National Wildlife Refuge	50,177
Pea Island National Wildlife Refuge	5,859
Pungo National Wildlife Refuge	15,000
Swan Quarter National Wildlife Refuge	15,501
	126,733

Source: USDOC/NOAA, 1978.

the U.S. Forest Service. Active wildlife management is practiced by the WRC in many of these areas.

There are no statutory controls that would govern pipeline routing and construction specifically in game lands, but the normal suite of regulations applicable to private and public lands would be in force. A number of transmission line, pipeline, and highway rights-of-way have been granted across WRC-owned lands. In one pipeline case, the WRC stipulated in the easement agreement that certain planting materials of value to wildlife be used in revegatating the right of way (Critcher, 1981).

The principal impacts of pipelines on refuges and game lands would be on wildlife habitat and ecosystem function. These have been discussed in a general way earlier, and the different areas are too many and diverse to permit more specific discussion here. Pipelines in general should avoid national wildlife refuges and the more productive and sensitive game lands, though under the right conditions and with appropriate mitigation, relatively benign pipeline crossings of these areas may be possible. A manual for managing oil and gas activities in coastal refuges based on experience in Louisiana and Texas was recently issued by the Fish and Wildlife Service (Longley et al., 1981).

8.12 AESTHETICS

The aesthetic impact of pipeline activities in coastal North Carolina will depend, as elsewhere, on two major factors: the sensitivity of the aesthetic resources (including not only landforms and vegetation, but also wildlife, air quality, noise quality, etc.) to pipeline construction and maintenance practices, and the site restoration methods employed. The aesthetic impact of the various pipeline ancillary facilities may be as great as or greater than that of the pipeline itself, and will be addressed later in Section 9.2.

There will be some short-term aesthetic impacts during the project's construction phase as a result of landform alteration and vegetation removal,

the presence of heavy equipment, noise, dust and other air emissions, and increased turbidity. These will be most acute in park and recreation areas and other places where concentrations of people and high scenic quality occur together. The more serious impacts will be longer-term, wherever complete restoration of the site is difficult or impossible. Straight-line right-of-way cuts through forests open up long, linear corridors to view that will persist for the life of the project. Where the revegetation of visible marshes, stream banks and areas prone to erosion proves difficult, there will also be a loss of visual quality.

Rerouting is the most effective means to avoid aesthetic degradation of a particular area and should be considered for wooded parks and other important visual resources. Where this is not practical, visually important environments should be restored as rapidly as possible, including the rebuilding of dunes and the replanting of trees in the construction right of way. Route alignment should be altered to eliminate long, straight views from highways and other public areas, and screen plantings of shrubs and small trees can be employed along forest edges. The Federal Energy Regulatory Commission's guidelines for applicants for certificates of public convenience and necessity (18 C.F.R. §2.69) describe several measures applicants should take to minimize gas pipeline right-of-way impacts. These include deflection of the right-of-way alignment and screen plantings at visible forest edges, and the avoidance of scenic areas where practical, or where impractical, the placement of the right-of-way "so as to be least visible from areas of public view and so far as possible in a manner designed to preserve the character of the area."

In coastal North Carolina, the most aesthetically important, pipeline-sensitive environments are forested areas (particularly forest edges), parks and recreation areas, and to a lesser extent (because restoration may be possible), views over marshes. Proposed routings through these areas should be examined critically for means to reduce visual impacts.

IX. OTHER CONCERNS

9.1 PIPELINE ACCIDENTS

Pipeline leaks and ruptures can and do occur. For the most part, the size and impacts of these leaks are minor, but under certain relatively rare circumstances, catastrophic spills of thousands of barrels from oil lines, and explosions and fires at gas lines, take place. Though the probability that leaks of any significant size will occur is relatively small, such a possibility must be considered in examining routing options.

The focus of this report is on the impacts and conflicts generated by pipeline installation and normal operation, and it is not our intent to provide a thorough treatment of the subject of pipeline breaks and spills. Such a treatment would require a separate report at least as bulky as this one. However, there are a few things that can be said by way of introducing the subject and placing the question of leaks in perspective.

Since both the statistics and impacts of offshore and onshore pipeline breaks are so different, these two environments are treated separately below.

9.1.1 Offshore

Of the two commodities, oil is by far the major environmental concern offshore. Very little is known about the impacts of natural gas on the marine environment, but evidence available so far suggests that the impacts do not begin to approach the severity of those from oil spills. For this reason, most of the following discussion will focus on oil leaks.

9.1.1.1 Causes of Pipleline Failure

To understand and realistically estimate the spill hazard presented by pipelines, the historical record of failure causes and rates must be examined. The most extensive record available is that accumulated during 35 years of offshore operations in the Gulf of Mexico, and this will serve as the basis for the discussion below.

Potential causes of pipeline failure include anchor dragging, corrosion, natural hazards, damage from fish trawling gear, machanical failure, operating error, and boat-pipeline collisions. In many cases, failure is not due to one cause alone; pipeline damage due to corrosion and chafing, for instance, may accumulate to the point at which failure is precipitated by an impact that would not have damaged an intact line.

Anchors. Pipelines kinked, cracked or ruptured by dragging anchors are one of the major sources of pipeline spills. Since 1970, over 70% of the total volume of oil reported spilled from pipelines in the Gulf was the result of dragging anchors (USDOI/GS, 1980), most of them associated with large oil-related vessels.

In preparation for the laying of the North Sea FLAGS gas line, Shell Exploration and Production conducted or commissioned a number of studies, some of which examined the risks of anchor-hooking along the route and the usefulness of burial for pipeline protection. Results of these studies (as

reported in Gowen et al., 1980) indicated that the effectiveness of burial varies depending on the type of anchor involved and the depth to which it penetrates the sediments. Most commercial vessels' anchors bury 0.5 - 3 meters (1.5-9.9 feet) deep, and burial below these depths should protect pipelines from these anchors. In the Gulf, for instance, MMS commonly requires pipeline burial to a minimum of 10 feet under shipping fairways and anchorages.

However, the Shell study also found that the large, 20,000 to 30,000 lb. anchors of large tankers and oil-related vessels (e.g., pipelaying and derrick barges) often penetrate much deeper, as much as 5-17 meters in good holding ground and even deeper in soft clays (Figure 9-1). Burial of pipelines beneath these depths, if feasible at all, is extremely expensive. Det Norske Veritas, a Norwegian agency involved in safety and risk analyses of offshore structures, also has concluded that there is currently no effective way of preventing pipeline damage by large anchors, and therefore recommends routing pipelines around areas of intense tanker or rig traffic (Nothdurft, 1980).

Corrosion. Corrosion (both external and internal) is by far the largest single cause of pipeline leaks, but these are usually pinhole leaks, releasing very small amounts of oil (usually less than five barrels). As corrosion protection systems continue to improve, the incidence of corrosion should drop.

Natural Hazards. A variety of natural hazards may cause a pipeline to crack or rupture. These include both catastrophic events such as fault movement or mass movement of sediments, and other processes such as scour and liquefaction that may expose the pipeline to stresses for which it was not designed.

Damage from Trawling Gear. Concern has been expressed that pipelines may be damaged by bottom trawling gear, and particularly by the large otter trawl doors used to keep the net open. During a four-year study, the VHL River and Harbour Laboratory at the Norwegian Institute of Technology examined the problem from both sides, i.e., the damage both to the pipeline and to the

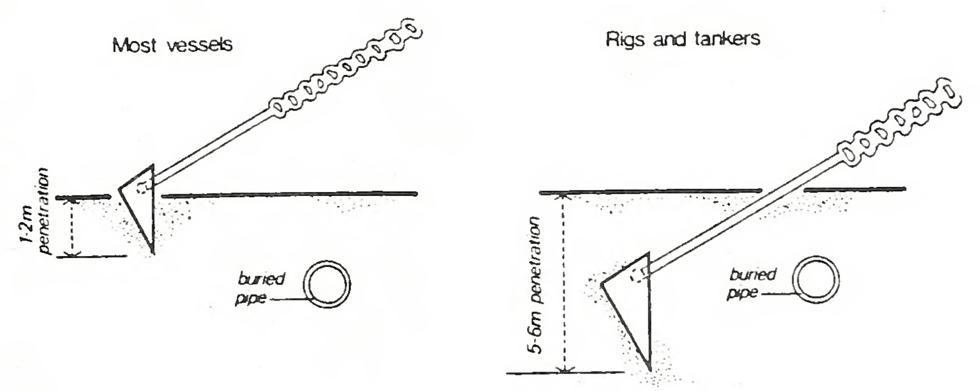


Figure 9-1. Anchor penetration. (from Nothdurft, 1980)

trawl gear as a result of pipeline/gear impacts. Two types of forces exerted by trawl doors that theoretically could damage a pipeline upon impact were investigated (Gowen et al., 1980):

1) The impact force as the door hits the pipeline. In tests with various sizes and shapes of doors, impacts were found to be insufficient to cause significant damage to the large-diameter, concrete-coated pipe used in the experiments.

2) The pullover force as the door drags over the pipeline. This force resulted in lateral movement of the line of less than 1.5 meters after five passes of the trawl door.

As a result of these findings, Shell Expro concluded that for their large-diameter FLAGS gasline: 1) trawl gear will neither penetrate the weight coat nor cause significant loss of concrete; and 2) the pipeline may be moved by pullover forces, but only slightly and well within acceptable tolerances (Broussard, 1979).

The Minerals Management Service is unaware of a single documented instance in the Gulf of pipeline damage caused by trawl doors (USDOI/GS, 1980). However, the agency does note frequent instances of trawling gear (nets, ropes, tickler chains, etc.) getting hung on pipeline-related obstructions such as taps and valves. Though such protuberances are required by current MMS policy to be buried below the mudline or be protected by valve coverings, they occasionally become exposed. There are several records of leaks from taps and valves caused by trawling gear.

Other Causes. A variety of other causes have been identified or implicated in pipeline spills. These include:

- equipment failure or malfunction, particularly in the system that monitors and controls leak detection and shut down:
- operator error;
- unnoticed damage during construction and testing, such as buckling, improper welds, and damage to the pipeline coating during trenching;
- impacts by boats, particularly at the platform where risers may be exposed, and impacts from equipment lost overboard, especially during transfer between boats and platforms; and
- chafing of the line against another object as a result of clamp slippage on risers, improper line crossings, or dragging cables or anchor chains. (Funge et al., 1977; NRC, 1981).

In their analysis, Funge et al. (1977) ranked potential causes of failure in terms of their environmental and economic cost, and in terms of probability of occurrence (Tables 9-1 and 9-2). When combined, these tables provide something of an agenda on hazards to be addressed in designing an offshore pipeline system.

9.1.1.2 Pipeline Leaks: Historical Record and Probabilities

Minerals Management Service records show a total of 337 pipeline failures reported in the Gulf of Mexico between 1967 and January 1981 (Table 9-3). Corrosion (internal and external combined) was the most common reported cause of failure, accounting for almost one-half of all pipeline leaks. Other commonly reported causes were anchor dragging, mechanical failure, construction or operator error, and natural hazards (mudslides, hurricanes,

Table 9-1

RATING OF POTENTIAL HAZARDS TO SUBMARINE PIPELINES

IN TERMS OF ECONOMIC AND ENVIRONMENTAL DAMAGE

CREATE EXTENSIVE DAMAGE

- External Corrosion - expensive to locate resulting leaks and perform repairs; unanticipated damage.
- Hurricanes and Severe Storms - unavoidable destruction.
- Earthquakes - may break lines and risers, and topple platform w/control equipment.
- Ship Accidents and Anchor Dragging - unexpected ruptures of lines and collisions with platform.
- Fishing - unexpected damage of lines (unlikely in Gulf of Mexico).
- Equipment Inadequacies and Malfunctions - could overstress pipes and other equipment.
- Vandalism and Sabotage - generally planned for greatest destruction.
- Internal Corrosion - progresses slowly until pipe is weakened and subject to overstress from external forces.
- Explosion and Fire - difficult to control on remote platforms.

CREATE MODERATE DAMAGE

- Sea State - breakage by forces that can be anticipated.
- Dredging - inadvertent damage that can be mitigated by alert pipeline operators and aerial inspection.
- Accidental Debris Discharge - rupture of pipe with repair hampered by debris.
- Unnoticed Damage During Construction - can lead to eventual leaks with expensive repairs.
- Material Deficiencies and Poor Quality Control - poor quality materials will lead to rapid deterioration and necessitate early replacement.

CREATE MINOR DAMAGE

- Marine Fouling - hamper inspection of riser and may conceal corrosion attack.
- Thermal Effects and Ice - protective systems can be installed, especially for risers.
- Abrasion - riser can be replaced or strengthened and protected.
- Soil Transport, Erosion & Bottom Phenomena - can be corrected before condition progresses to worse condition.
- Operator Errors - potential spill conditions can be detected by back-up and monitoring systems.
- Design Deficiencies - minor errors; major errors will normally be spotted during checking and corrected; minimized by employment of experienced designers.

(from Funge et al., 1977)

Table 9-2.

RATING OF POTENTIAL HAZARDS TO
SUBMARINE PIPELINES BY PROBABILITY
OF OCCURRENCE

MOST PROBABLE:

- External Corrosion
- Ship Accidents & Anchor Dragging

EXPECTED OCCURRENCE:

- Soil Transport, Erosion & Bottom Phenomena
- Operator Errors
- Equipment Inadequacies and Malfunction
- Unnoticed Damage During Construction
- Internal Corrosion

LEAST PROBABLE:

- Sea State Exceeding Design
- Marine Fouling
- Thermal Effects and Ice
- Abrasion and Chafing
- Hurricanes and Severe Storms
- Earthquakes
- Dredging
- Accidental Debris Discharge
- Vandalism & Sabotage
- Explosion and Fire
- Fishing
- Design Deficiencies
- Material Deficiencies
- Poor Quality Control

(from Funge et al., 1977)

Table 9-3. Pipeline Failures in the Gulf of Mexico, 1967 - January 1981.

Cause	Number of Failures	Percentage
Corrosion	163	48
Anchor-dragging	47	14
Mechanical failure or construction/operation error	32	9
Natural events: mudslides, hurricanes, wave action, other	19	6
Trawling	5	1
Boat impact	4	1
Chafing	3	1
Other	18	5
Unknown or not reported	46	14
Totals	337	99

Source: Compiled from USDOI/GS, 1981.

and wave action on carrier pipe and risers). Causes combined in the "Other" category include equipment (other than anchors) dragged across or dropped on lines, jet sled damage, abandonment of line, and pipeline crossings.

During this period, records indicate that at least 209,500 barrels of oil spilled from these leaks (the estimate is very approximate, as several spills were recorded by area of slick and not volume spilled, and spill reporting did not become mandatory until 1971). Most of those 210,000 barrels spilled were due to a single accident in 1967, when an anchor-caused leak spewed more than 160,000 barrels of oil into the Gulf over a ten-day period before it was detected. Since 1971, when spill reporting became mandatory, an estimated 34,690 barrels of oil have been lost as a result of approximately 225 liquid pipeline accidents. Most of this oil was spilled in a few large spills: 98% of the total was lost from the 16 spills of more than 50 barrels each (figures compiled from USDOI/GS, 1981).

Danenberger (1976) analyzed the figures on oil spills in the Gulf OCS from all sources for the years 1971-75, and while his data are old, they are still useful for setting pipeline spills in perspective (Tables 9-4 to 9-6). As the tables show, pipeline leaks and breaks accounted for more that half of the total volume of oil spilled during this period, largely as a result of a few large spills.

From 1967 to July 1979, production of oil and concentrate in the Gulf totalled approximately 3.99 billion barrels, yielding a pipeline spillage rate of 0.0052% (USDOI/BLM, 1981c). If the large spills before 1971 are subtracted, the spill rate for the last decade is considerably lower. Based on historical data such as this, BLM (1981c) (now MMS) has attempted to estimate the number and size of leaks that would result from Sale 56

Table 9-4. Causes of oil spills of more than 50 barrels, 1971-75, Gulf of Mexico Outer Continental Shelf.

Cause	Number of spills	Total volume (bbl)	Volume (bbl) per spill	
			Maximum	Minimum
Production-platform equipment malfunction or misuse............	6	10,925	9,935	75
Pipeline leaks and breaks..........	7	27,396	19,833	70
Drilling and workover mishaps......	0	0	0	0
Barge spill (leak; or oil transfer)....................	2	7,100	7,000	100
Workboat spillage during unloading of diesel fuel; or collision with platform....................	3	506	240	100
Other causes.......................	2	320	200	120

Table 9-5. Causes of oil spills of 1-50 barrels, 1971-75, Gulf of Mexico Outer Continental Shelf.

Cause	Number of spills	Total volume (bbl)	Volume (bbl) per spill		
			Average	Maximum	Minimum
Production-platform equipment malfunction or misuse............	536	2,286	4.26	50	1
Pipeline and pump failure..........	232	1,105.5	4.75	35	1
Drilling and workover mishaps......	20	64.5	3.23	10	1
Miscellaneous-equipment failures and employee errors..............	84	440	5.24	36	1

Table 9-6. Causes of 1- to 50-barrel spills from pipelines and pumps, 1971-75, Gulf of Mexico Outer Continental Shelf.

Cause	Number of spills	Total volume (bbl)	Volume (bbl) per spill		
			Average	Maxi-mum	Mini-mum
Pipeline leaked.........................	63	303.5	4.82	35	1.5
Pipeline ruptured.......................	20	161	8.05	32	2
Discharge or transfer line ruptured or coupling failed...................	54	237	4.39	27	1
Pipeline pump failed....................	42	211	5.02	20	1
Pig trap leaked.........................	12	35	2.92	10	1
High-low pressure sensor failed.........	3	18	6.00	8	4
Fuel line leaked........................	2	3	1.50	2	1
Pump capacity exceeded..................	1	2	2.00	2	2
Miscellaneous...........................	39	152	3.90	12	1

(Source: Danenberger, 1976)

activities, assuming all leases were sold. Their estimated number of spills over 50 barrels in the South Atlantic OCS area ranges from one, based on comparisons of pipeline mileage, to 11, based on comparisons of production. The volumes of oil estimated to be spilled, based on production data, range from approximately 41,500 to 108,900 barrels to be spilled during an estimated 4 to 11 spills, with an estimated average spillage of 9,800 barrels per incident.

Several factors combine to make such estimates practically worthless, however, and to limit the value of historical data in general. These are:

1) Environmental conditions off North Carolina are substantially different from the Gulf. Average weather and oceanographic conditions are more severe, the water is deeper, mud slides are unknown, and other characteristics of the sedimentary environment are different.

2) The distribution of hydrocarbon resources in the two regions appears to be quite different, with the resources in the South Atlantic concentrated much further from shore. As a result, oil found off North Carolina is less likely to be piped, and any piping to shore will be accomplished with a few medium- to large-diameter pipelines, rather than many smaller ones more susceptible to damage. Small-diameter gathering lines will be laid only in deep water at the edge of the shelf and on the slope, where many common pipeline hazards are absent or far less worrisome.

3) The statistics used by BLM include the major spills of the 1960's, and the record for the 1970's is far better, as noted above. Part of the reason for the improvement is the promulgation of new regulations, beginning in 1969, that among other things require the installation of pipeline-related platform safety equipment to monitor operating pressures and to automatically shut in a line when a pressure drop is detected. The use of 1960's data to calculate spill rates ignores the substantial influence of these regulations and other improvements in reducing the size of spills during the 1970's.

4) Related to this last point, technical improvements in corrosion protection and other areas continue to be made. Since new pipelines will be designed and laid with state-of-the-art technology, they will perform more safely, under similar circumstances, than many of the ten- and twenty-year old pipelines whose performance is documented in the pipeline leaks statistics.

Three basic conclusions can be drawn from this discussion. First, small leaks and spills of a few barrels or less, as a result of corrosion, operator mistakes, leaky valves, etc., are almost inevitable. Second, large leaks will account for the majority of the oil spilled, but will be quite rare. Third, analysis of the historical record alone is insufficient to provide a realistic estimate of the amount of oil that may be spilled off North Carolina from pipeline breaks; furthermore, given the highly probabilistic nature of such events, no realistic estimate of any kind may be possible.

9.1.1.3 Consequences of Oil Pipeline Leaks

Given that an oil spill of a certain size occurs at a given location, two major factors will determine the consequences of the spill. First, where will the slick travel and with what resources will it come in contact? Second, what will be the effect of the oil on those resources?

Oil Spill Drift. Where the spilled oil winds up depends largely on surface winds and currents. Using existing wind and current data, and given a spill location and time of year, oil spill trajectories can be approximated.

Such an analysis has recently been conducted by Samuels and Lanfear (1980) for the South Atlantic. The purpose of their study was to estimate the probabilities that an oil spill occurring at a particular point would reach various environmental features or sections of coast within a certain period of time. To do this, likely production fields and transportation routes were selected. Using available environmental data, 500 oil spill trajectories were then simulated in Monte Carlo fashion for each of the four seasons from each of the potential spill sources. For transportation routes, the source was represented as a straight line with potential spills uniformly distributed along that line.

Eleven transportation routes off North Carolina were selected (Figure 9-2). Of most interest in this study are T1 through T5, the hypothetical pipeline routes, and T17 and T28, which run almost to shore, although they also extend seaward of the lease blocks and are intended to represent tanker routes. Oil spill targets consist of selected environmental resources (Table 9-7) and the oceanfront coastline, divided into segments of equal length (Figure 9-3).

The results of their simulations are shown in Table 9-8, which lists the probabilities that spills occurring on these routes will contact selected environmental resources or coastline segments within 30 days (see Samuels and Lanfear, 1980, for more extensive explanations and results). Three points should be made about this analysis. First, the probabilities are by no means insignificant, particularly for the four routes (T3, 5, 17 and 28) that approach land. Second, it is important to keep in mind what these figures represent: the probability that an oil spill, occurring at a random point on a particular line, will come into contact with a particular environmental resource. These are conditional probabilities, and do not include the probability that an oil spill will occur along that route. To obtain the probability that a resource will be contacted by an oil spill if a pipeline is built along one of these routes (which is the probability of greatest real interest), the two probabilities must be multiplied. As was discussed in the previous section, the latter probability is both very small and very difficult to estimate. Finally, the limitations of their method must be kept in mind. These include the location of the routes (by no means the full set of most likely routes), the assumption of uniform spill probability along a route, and the inability to consider resources within the estuaries.

Effect of Oil on Environmental Resources. There is a voluminous literature on the effects of oil on marine and estuarine environments, and it is well beyond the scope of this report to review that literature here. One of the most respected sources on the subject is NAS (1975); other references of value are Evans and Rice (1974), AIBS (1976,1978), USDOI/BLM (1978, 1979) and Sanders (1981). In addition, a recent study examined the potential impacts of oil spills on Brunswick County, North Carolina (Kenneth Creveling Associates, 1982). The study had two objectives: 1) to determine the potential economic and related effects of increased tanker traffic on the recreational resources and activities of Brunswick County shoreline communities, and 2) to identify

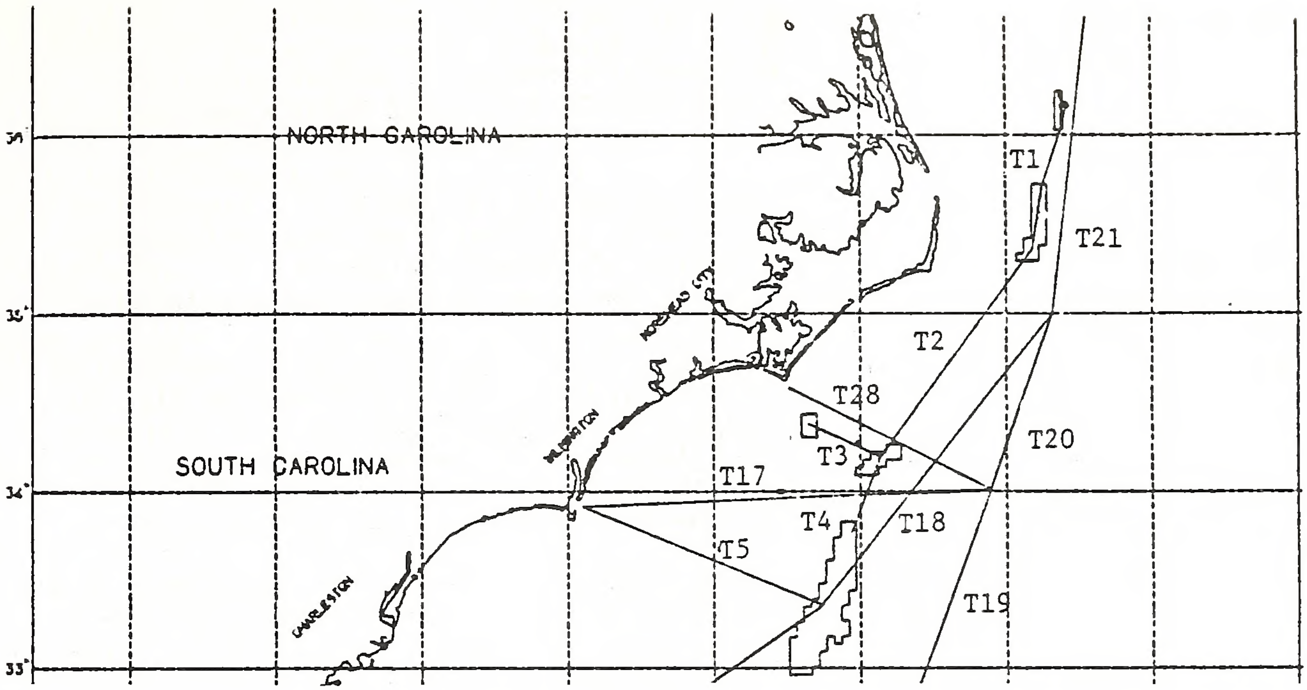


Figure 9-2. Transportation routes used in the Samuels and Lanfear (1980) model.

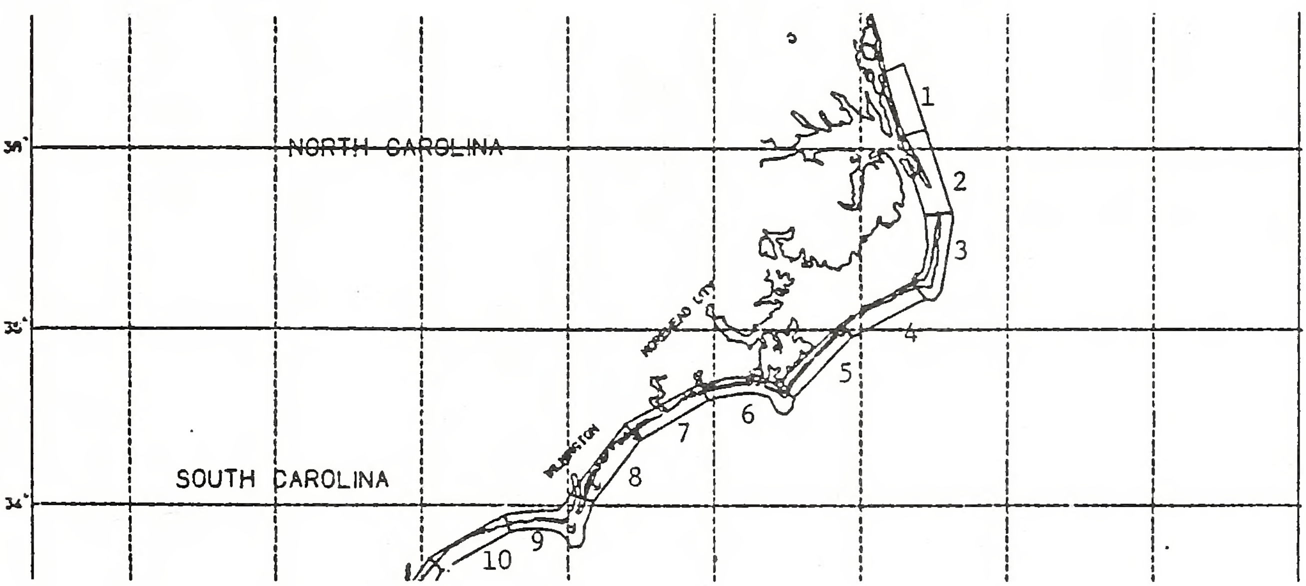


Figure 9-3. Land segments used in the Samuels and Lanfear (1980) model.

Table 9-7. Selected environmental resources chosen as targets for Samuels and Lanfear's (1980) oil spill simulation model.

Brown Pelican Rookeries (Vulnerable all year)
Marine Turtle Nesting Habitat (Vulnerable May through October)
Onslow Bay Live Bottom Area (Vulnerable all year)
Federal and State Wildlife Conservation Areas (Vulnerable all year)
Federal and State Parks (Vulnerable May through October)
Federal and State Parks (Vulnerable November through April)
Monitor Marine Sanctuary (Vulnerable all year)
Tourist Beaches, N.C. (Vulnerable May through October)
Coastal Inlets, N.C. (Vulnerable all year)
Historic Sites (Vulnerable all year)

Note: Data sets included all occurrences of these resources between North Carolina and Cape Canaveral, Florida, unless otherwise specified.

Table 9-8. Probabilities (expressed as percent chance) that an oilspill starting at a particular location will contact a certain target or land segment within 30 days.

Target	T1	T2	T3	T4	T5	T17	T18	T19	T20	T21	T28
Brown Pelican	n	1	4	1	17	11	n	n	n	n	3
Marine Turtle	1	9	17	9	15	13	4	n	1	1	15
Onslow Bay Live Bot.	n	3	28	4	66	50	1	n	n	n	13
Wildlife Conser.	3	2	1	1	2	2	1	n	1	2	1
Parks (May-Oct)	1	11	20	10	22	18	5	n	1	1	17
Parks (Nov-Apr)	2	7	14	7	14	11	3	1	1	2	14
Monitor	1	20	23	14	9	8	7	1	2	n	17
Tourist Beaches, NC	1	11	19	10	18	14	5	n	1	1	16
Coastal Inlets, NC	3	8	20	8	32	25	3	n	1	1	19
Historic Sites	3	18	29	16	21	18	8	1	2	2	24
Land	5	15	29	15	35	27	7	1	3	4	26
Land Segment 1	n	n	n	n	n	n	n	n	n	1	n
Land Segment 2	3	2	1	1	n	n	1	1	1	3	1
Land Segment 3	2	6	5	4	2	2	3	1	1	1	5
Land Segment 4	n	6	12	7	4	4	2	n	1	n	9
Land Segment 5	n	1	5	2	3	2	n	n	n	n	6
Land Segment 6	n	n	3	1	7	5	n	n	n	n	3
Land Segment 7	n	n	n	n	4	3	n	n	n	n	1
Land Segment 8	n	n	1	n	7	6	n	n	n	n	1
Land Segment 9	n	n	1	n	7	4	n	n	n	n	n

Note: n = less than 0.5 percent

Source: Samuels and Lanfear, 1980.

strategies and measures to reduce adverse impacts of oil spills on the resources and economics of coastal sections of the county.

Of particular interest in considering the siting implications of possible oil spills are the series of studies by Miles Hayes and others at Research Planning Institute, Inc. (RPI) on the sensitivity of specific coastal environments to spilled oil (e.g., Hayes et al., 1980; Thebeau et al., 1981). Based on a number of studies by Hayes and others, researchers at RPI have compiled a general index of the relative oil sensitivity of coastal environments (or rather shoreline environments, as subtidal habitats are not considered). Researchers included consideration of both the physical longevity of the oil in each environment in the absence of clean-up efforts, and the oil's biological effects. The index has been used by them in preparing maps for use in responding to oil spills; the value of the index is in helping to choose protection priorities and clean-up strategies. Such indices are obviously also applicable to the question of siting facilities such as pipelines that may generate oil spills.

RPI recently conducted a study of the oil sensitivity of the South Carolina coastline (Thebeau et al., 1981). In that study the index, known as the Environmental Sensitivity Index, listed the following shoreline environments in order of increasing relative sensitivity to spilled oil:

- 1) Exposed vertical seawalls
- 2) Wavecut platforms (not present in South Carolina)
- 3) Fine-grained sand beaches
- 4) Medium- to coarse-grained sand beaches
- 5) Exposed tidal flats (low biomass)
- 5a) Mixed sand and shell beaches
- 5b) Sheltered erosional scarps
- 6) Shell beaches
- 6a) Exposed rip-rap
- 7) Exposed tidal flats (moderate biomass)
- 7a) Erosional scarps in marsh
- 8) Sheltered coastal structures
- 9) Sheltered tidal flats (high biomass) and oyster beds
- 10) Marshes

9.1.2 Onshore

9.1.2.1 Pipeline Failure: Causes and Statistics

The Materials Transportation Bureau of the U.S. Department of Transportation maintains a reporting system for the purpose of gathering and analyzing accident data from pipeline operators and carriers. Statistics on the numbers and causes of pipeline failures during 1978 and 1979 are presented in Table 9-9 for gas transmission and gathering systems, and Table 9-10 for liquid pipelines, including both crude oil and products lines. (Crude oil lines accounted for 55% of the liquid pipeline accidents during these years, and 31% of the volume of commodity lost; the average loss for crude oil line accidents was 924 barrels/break.) These statistics include both offshore and onshore lines, but the vast majority are onshore. Table 9-11 presents pipeline accident rates for both liquid lines and gas gathering and transmission lines before 1977. Since most of these lines and accidents are

Table 9-9. Accidents and Casualties Reported by Gas System Operators of Transmission and Gathering Lines, 1978-79.

Cause	Number of Failures	% of Total	Number of Fatalities	Number of Injuries
Corrosion	163	16.6	0	3
Damage by Outside Forces	519	52.8	13	82
Construction Defect or Material Failure	220	22.4	0	17
Other Causes	81	8.2	10	79
Total	983		23	181

Sources: USDOT/MTB, 1981a,b.

Table 9-10. Liquid Pipeline Accident Summary, 1978-79.

Cause	Number of Accidents	% of Total	Loss (Barrels)	Number of Fatalities	Number of Injuries
Internal Corrosion	27	5.3	12,571	0	3
External Corrosion	82	16.2	47,761	1	0
Defective Weld	25	4.9	37,405	0	1
Incorrect Operation by Carrier Personnel	27	5.3	28,479	0	2
Defective Pipe	19	3.8	41,058	0	0
Equipment Rupturing Line	170	33.6	224,737	3	4
Other	156	30.8	437,128	3	11
Total	506	100	829,139	7	21
Crude Oil Pipeline Totals	278		256,995	0	4

Sources: USDOT/MTB, 1981a,b.

Table 9-11. Pipeline Accident Rates, 1970-76.

	Liquid Pipelines			Gas Pipelines (Transmission and Gathering)		
Year	Reported Number of Accidents	Reported Number of Trunk Pipeline Miles	Accident Rate Per 1000 Miles	Reported Number of Accidents	Reported Number of Trunk Pipeline Miles	Accident Rate Per 1000 Miles
1970	351	122,365	2.87	343	286,486	1.20
1971	310	122,471	2.53	410	285,482	1.44
1972	306	124,458	2.46	409	282,944	1.45
1973	273	122,354	2.23	471		
1974	256	126,211	2.03	460	284,318	1.62
1975	254	121,278	2.09	394		
1976	212	126,457	1.68	543		

Sources: USDOT/MTB, 1981a,b; FERC, 1980.

onshore, and since conditions in North Carolina are generally comparable to other onshore areas, these statistics can provide rough, order-of-magnitude estimates of likely trunk line accident rates in North Carolina.

The major causes of onshore pipeline failure are: corrosion, damage by outside forces, equipment or material defects, and incorrect operation.

Corrosion. Corrosion as a cause of pipeline failure declined steadily during the late 1960's and early 1970's. Liquid pipeline failures attributed to corrosion, for instance, dropped from 229 in 1968 to 54 in 1976. Most of this reduction was due to the promulgation of industry standards and federal regulations (49 C.F.R. §§192 and 195) regarding pipeline coatings and cathodic protection systems. Analysis of accident data shows that of the more than 1000 corrosion-related failures between 1968 and 1976, 87% were caused by external corrosion, and more than 2/3 of these occurred in noncoated (bare) pipelines (NTSB, 1978).

Damage by Outside Forces. Damage by outside forces is currently the largest cause of pipeline accidents and fatalities, and most pipeline carriers regard such damage as their greatest safety problem. The most common source of such damage is heavy excavation or earthmoving equipment operated by someone other than the pipeline company, such as contractors engaged in highway, utility, residential or industrial construction. There are several ways to minimize the probability of such damage, most of which focus on informing construction contractors of the pipeline's presence. In 1973 the National Transportation Safety Board issued a report that discussed third party damage and preventative measures in depth (NTSB, 1973).

Material Failures and Operational Errors. Types of failure in this category include failure of the pipe material, failure of the steel-mill-produced longitudinal weld, failure of the field-produced girth weld, and operational error as a result of human error or system malfunction.

A wide variety of causes are lumped in the "Other" category, including natural hazards (earthquakes, landslides, floods and ground settlement), pump failure, tank failure, valve malfunction, vandalism, and cold weather.

9.1.2.2 Consequences of Onshore Pipeline Failure

As in the offshore environment, the consequences of pipeline failure for oil and gas lines onshore are very different. The severity of oil spill impacts onshore will depend on: the volume and character of the crude oil lost; the location of the spill; local topography, the presence of surface waters, soil characteristics and other aspects of the general environment; the season of the year; and the emergency procedures employed. Minor leaks may continue for days or weeks before being detected and repaired, and may first be discovered by vegetation discoloration, seepage from the ground, the presence of a slick on surface waters, or changes in groundwater odor and taste. Major terrestrial spills may result in the destruction of some vegetation and wildlife, habitat loss, air pollution, soil contamination, and fire and explosion hazards. The areal extent of such impacts is generally rather limited, unless the spilled oil either enters surface waters, where it will have deleterious if not lethal effects on aquatic organisms along what

may be a substantial length of stream, or moves downward to contaminate the water table (FPC, 1976).

Natural gas behaves very differently when released from pipelines and presents very different hazards. Gas slowly leaking from a pipeline will kill all vegetation in the vicinity of the leak as the gas displaces oxygen in the root zone, but it then dissipates into the atmosphere with no direct impact on humans or animals. Major leaks and breaks in high pressure gas lines, on the other hand, are extremely hazardous and not uncommonly cause serious injuries or fatalities. From 1970 to 1978, 335 incidents resulting in gas pipeline rupture occurred. Two hundred of these incidents resulted in gas ignitions, 72 in explosions, and 63 in secondary explosions or fires (as when escaping gas infiltrates an enclosed structure and is accidentally ignited) (FERC and USDOI/BLM, 1981).

9.2 ANCILLARY FACILITIES

The various ancillary facilities associated with pipeline construction and operation were discussed in Section 3.7. These can be divided into four groups:

1) Permanent onshore facilities located along the pipeline route, including valve and meter stations, pump stations, compressor stations, and gas separation and/or processing plants.

2) Temporary onshore facilities not necessarily on the pipeline route that provide materials or services in support of pipeline construction; these include pipe coating and/or storage yards, service bases for offshore construction, and a variety of other firms.

3) Offshore intermediate pressure booster stations.

4) Access and service roads, borrow pits, disposal piles and other minor features along the pipeline route.

In siting a pipeline, not only must the impacts of the pipeline be considered, but also impacts of the ancillary facilities that are located along it. A certain section of route might be optimal in terms of minimizing the impacts of the pipeline itself, but if a compressor station must be located within that section, another route might be preferable. In most cases, there is a certain amount of flexibility in siting these facilities along a pipeline.

A full discussion of the impacts and siting implications of these facilities would require several volumes by itself and is beyond the scope of this report. The intention here is simply to mention what would be some of the highlights of that discussion, and to inform readers of the various considerations involved; references are made to sources of additional information. Facilities listed in item 2) above, such as pipe coating yards and construction service bases, are not discussed here, as pipeline siting will be influenced by them only peripherally. More information on these facilities can be found in NERBC (1976).

9.2.1 Permanent Onshore Facilities Along the Pipeline Route

Several aboveground facilities may be built along the pipeline wherever the hydrocarbon stream must be manipulated in some way. These include valve and meter stations, pump stations for oil lines, and compressor stations and

separation and dehydration plants for gas lines. For the most part, the impacts of constructing these facilities will be similar to those of constructing other industrial plants, and such impacts (e.g., air and noise pollution, soil erosion, loss of vegetation, wildlife disturbance, etc.) will not be further discussed here. As with any industrial plant, what makes these facilities unique is their operational impacts, which are set out by category below.

Land Use. At each aboveground facility location, a certain amount of land will be removed from its previous land use (e.g., forestry, agriculture, natural woodland) for the service life of the line, at a minimum. Meter stations generally require one to five acres of land (NERBC, 1976), and since such facilities have no air, water or noise emissions and are generally unobtrusive, this preemption of land use will be their only significant impact.

NERBC (1976) lists the land requirements of compressor stations as being 30 to 80 acres, but the upper figure appears to be excessive. Compressor stations on the North Border pipeline now under construction will average 20 acres in size, and the stations on Florida Gas' Louisiana to Florida line range from 10 to 40 acres each (USDOI, 1976; FPC, 1976). Pump stations on oil lines may require 10 to 80 acres, depending on whether the station is simply an intermediate booster station, or whether it occurs at the beginning, end or juncture of lines, where storage tanks may be necessary. Gas separation and dehydration plants generally require about 50-75 acres of land, more than half of which is used as a safety buffer (NERBC, 1976).

Air Quality. Hydrocarbon leaks and emissions from engines, pumps and turbines will be the two sources of air pollutants at pressure booster stations. Hydrocarbons may leak from pump and compressor seals, relief valves, and pipeline valves, but the amounts will be small and their impact minimal (NERBC, 1976). Most oil pipeline pump stations are operated with electric power, so that there will be no emissions from hydrocarbon combustion. Electric pump motors produce ozone, but in insignificant amounts (FERC, 1980).

Gas pipeline compressors are usually powered by natural gas from the line. Both reciprocating engines and gas turbines are used, though the trend is towards large gas turbines, which emit fewer pollutants but are also less efficient. USEPA (1977) presents emission data for both types of compressor engines. The major pollutant is NO_x, but lesser amounts of carbon monoxide and hydrocarbons are also emitted.

The emissions of gas separation and dehydration plants will depend on the volume and composition of the gas processed, the plant design (including the various processes and equipment used), and the pollution control equipment installed (NERBC, 1976). Sources of emissions include processing emissions (mostly sulfur), evaporative emissions, flaring in emergency situations, and combustion emissions from industrial boilers, compressors and vehicles. The major sources will be the compressor engines (already discussed above), and acid gas wastes removed during processing. Sulfur, emitted as sulfur dioxide, is the only significant component of the latter, and the amount emitted will depend on whether sulfur is recovered from the gas stream and whether the tail gases are treated. With the use of a Claus plant and a tail gas plant in combination, it is possible to remove virtually all (99.8%) of the sulfur

present in the raw gas. International Research and Technology Corp. (1977, as reported in USDOI/BLM, 1981c) considered the potential environmental consequences of a gas separation plant built in the South Atlantic region, and concluded that there would be no significant impact on local air quality.

The operation of both pressure booster stations and gas separation plants must comply with applicable North Carolina and federal air pollution laws and programs; see Cribbins (1981) for a detailed discussion of these. Three basic programs will govern emissions from these facilities. First, a State Air Quality Permit is required from the N.C. Division of Environmental Management (DEM) to operate any air contaminant source in the state. Applications are evaluated in terms of an area's ambient air quality standards and the emission control standards set by DEM for various sources.

Second, under the Prevention of Significant Deterioration Program established by EPA and now administered by DEM, a permit is needed in areas attaining National Ambient Air Quality Standards (which includes the entire coastal area) if a source either 1) emits more that 250 tons per year of a listed pollutant, or 2) emits more than 100 tons per year if it is one of several listed facilities, which pressure booster stations and gas separation plants are not. Various criteria must be met for permit approval, including demonstration that the emissions will not cause significant deterioration of air quality (as defined in the regulations), and that pollution controls representing the "best available control technology" will be used.

New Source Performance Standards have been issued by EPA (40 C.F.R. §60) for new emission sources in certain categories. Of the various processes and equipment possibly associated with oil and gas pipelines, standards have been established for stationary gas turbines and sulfuric acid plants, the latter of which may be built to use sulfur recovered from the gas stream.

<u>Water Use and Quality</u>. Only gas separation and dehydration plants, among the facilities being discussed, use and discharge substantial quantities of water. Figures available from the gas separation industry in 1973 indicated a water demand for gas plants ranging from zero to 750,000 gallons per day, with most plants using less than 200,00 gallons per day (NERBC, 1976). How much water is used depends largely on the gas throughput and the cooling process employed. Modern air-cooled systems use far less water than water-cooled systems, which themselves vary in their water requirements depending on whether cooling towers or other recycling systems are used.

The water may be obtained from wells, surface waters or municipal systems. The withdrawal of such large amounts of water from surface or ground waters may create problems if surface flows are reduced or the water table lowered substantially. Under N.C. General Statute §143-215 Part 2, the Environmental Management Commission is empowered to designate "capacity use areas," within which a permit is needed to withdraw 100,000 gallons or more per day from surface or groundwaters. One capacity use area currently exists in the coastal zone, covering all of Beaufort, Pamlico, and Washington Counties and portions of the counties of Carteret, Craven, Hyde, and Tyrrell.

Several types of wastewater will be generated by gas separation and dehydration plants. These are:

1) Domestic wastewater, in limited amounts because of the small number of employees.

2) Cooling water, which may represent up to 70-100% of the wastewater effluents of a gas plant. The amount generated will depend on the cooling process and the quality of the incoming water (high quality water can be recycled more often). Pollutants in the discharge water will include heat, substances originally present but concentrated by evaporation, and chemicals added to reduce corrosion and fouling within the tower and condenser system. The latter include sulfuric acid, chromium, and chlorine, all of which may be highly toxic to aquatic life.

3) Process wastewater. This consists of salt water separated from the gas and water vapor driven off in the dehydration phase. Water vapor is not defined as a pollutant and is simply discharged into the atmosphere. The small quantities of salt water separated from the gas can be stored on the site and are transported only periodically from the plant site by truck. The method of salt water disposal depends upon local conditions, and methods chosen must receive formal approval from appropriate state and federal agencies.

4) Boiler wastewater. Various chemicals may be added to boiler water to minimize corrosion, sludge and scale, and these chemicals are discharged occasionally with boiler blowdown.

Greater detail on these discharges, their impacts and control may be found in NERBC (1976).

These discharges and their available control technologies will be reviewed in connection with the National Pollutant Discharge and Elimination System (NPDES) permit required from the N.C. Division of Environmental Management (DEM) and the 401 Water Quality Certification from DEM that will probably be required as well (see Cribbins, 1981, for more detail).

Noise. A major pollutant generated by these facilities, and probably the chief noxious pollutant of pump and compressor stations, is noise. Though noise levels are highly localized, they will not be restricted to normal working hours, but will be generated twenty-four hours a day.

The Environmental Impact Statement for the planned Florida Gas products line from Texas to Florida provides typical figures for noise impacts from pump station operation (FERC, 1980). The electric motors used to power that system's pumps will generate up to 5000 hp. each and produce an 82 dB(A) sound level 50 feet from the source. The actual impact on sound levels will depend on source characteristics (the number and horsepower of the units, the suction inlet pressure, and the direction of the receptor from the source), as well as other factors mentioned in the noise section in Chapter VII, such as ambient noise levels, physical characteristics of the area, and distance of the receptor from the source. In calculating the noise impact of their system of pump stations, assuming three 5000 hp. units at each station and a worst case combination of factors, Florida Gas found that houses approximately 600 feet from the stations would experience noise levels of 60-68 dB(A), in excess of EPA's proposed standard L_{dn} of 55 dB(A) even before normalization.

NERBC (1976) reports that compressor station engines and turbines generally will be audible within 6000-7000 feet of the station site, and that noise levels will be 66-71 dB(A) at station boundaries if the compressor units have built in silencers. The 30,000 hp. compressor stations on the North

Border pipeline will generate noise levels greater than an L_{dn} of 55 dB(A) for an area extending approximately 6600 feet from the site; the comparable radius for the 13,500 hp. stations is 5300. By acoustically treating the compressor building and by treating the turbine intakes and exhausts with additional silencing equipment, these distances can be reduced to 4900 feet and 3800 feet, respectively (USDOI, 1976).

A second source of noise at compressor stations will be blowdowns conducted at compressor stations during emergencies and for maintenance purposes (the latter will occur about once each year). The blowdown may either be of the compressor, taking approximately five minutes, or of a pipeline section ending at a station (unit blowdown), which may last 45 minutes (USDOI, 1976). The noise levels expected to be generated by these operations for the North Border pipeline are listed in Table 9-12.

Station noise levels can be reduced with mufflers and building design, as mentioned above, and silencers can probably reduce blowdown noise by 30 dB(A) (USDOI, 1976). Even so, noise levels will still exceed EPA's proposed standard for a radius of several thousand feet. A serious effort should be made to site the stations where the fewest people will be affected, particularly at night. A noisy industrial area, if crossed, would be ideal, but barring that unlikely circumstance, sparsely populated rural areas are preferable. Unfortunately station engines will be audible for greater distances in rural areas because of low ambient noise levels, but if the criterion for siting such facilities is to minimize the number of people affected and not the area, rural areas will usually be preferable to more densely settled but noisier urban areas. In any case, stations should be designed and outfitted to achieve maximum feasible noise suppression in all but the least populated areas. Furthermore, the pipeline company should be expected to conduct noise studies at proposed station sites, as well as along the line for several miles in each direction, examining not only current population but expected development trends.

Gas separation plants also generate noise from their compressors, boilers, flare stacks, and scrubbers. The noise produced may exceed ambient levels for distances at least as great as those of compressor stations. Control technologies are available for most of these sources and

Table 9-12. Estimated noise levels for compressor station blowdowns without silencing measures, North Border Pipeline.

Distance (Feet)	16 Inch Valve Vent	10 Inch Valve Vent	Unit Blowdown
100	115 dB(A)	113 dB(A)	108 dB(A)
300	105 dB(A)	104 dB(A)	98 dB(A)
1000	94 dB(A)	93 dB(A)	87 dB(A)
3000	84 dB(A)	82 dB(A)	75 dB(A)

Source: USDOI (1976).

include mufflers, enclosure of equipment, and, for flare stacks, multiport injector systems (NERBC, 1976).

Aesthetics. Gas separation plants have the greatest potential for aesthetic impact as a result of their physical appearance, noise levels, odors (particularly from incomplete combustion of hydrogen sulfide), and lighting. Landscaping can reduce visual impacts, though its use is limited by the need to maintain a large buffer zone of noncombustible material around the plant. Hydrogen sulfide emissions can be reduced by improving combustion efficiency.

Pump and compressor stations will also have both visual and auditory aesthetic impacts. While most of the facilities can be hidden by adequate landscaping, microwave communication towers, if used, may be quite prominent. All of these facilities should avoid highly visible natural landscapes when possible.

9.2.2 Offshore Booster Station

There is usually sufficient pressure, either within the producing formation or from pumps and compressors at the production field, to drive the oil or gas within the pipeline to shore. Occasionally, however, such pressure sources are not sufficient and an intermediate booster station becomes necessary to maintain proper operating pressures. The major factors which determine whether an intermediate booster station is needed include the length and diameter of the pipeline, the characteristics of the fluids being transported (i.e., viscosity, specific gravity, and whether liquids and gases have been separated or are being transported together), and the bottom characteristics of the route (slope, topography, and depth) (NERBC, 1976).

The potential impacts of an intermediate booster station consisting of pump or compressor equipment on an offshore platform can be grouped into three categories:

Air quality. Both pump and compressor engines will generate emissions that will degrade local air quality. Considering the relatively small emission levels of these engines and the general westerly winds, it is extremely unlikely that emissions off North Carolina will degrade onshore air quality. Under the authority of the Outer Continental Shelf Lands Act Amendments of 1978, USGS (now MMS) has promulgated regulations (30 C.F.R. §250.57) containing procedures both for determining whether emissions from OCS facilities will significantly affect onshore air quality, and for reducing such emissions if significant degradation will occur.

Pollution risk. The risers, valves, pumps and other portions of offshore booster stations create a greater risk of pipeline leakage or rupture as a result of material or equipment failure, construction or operational error, accidental damage, and natural hazards than would exist in the absence of the booster station. Such a risk is very difficult to quantify, though based on historical records, a substantial spill is unlikely.

The physical presence of the platform. The construction and physical presence of a large steel platform in the offshore environment will have several probable effects. Installation of the platform will disturb the bottom sediments, temporarily reducing faunal populations and productivity. This

will be of greatest concern in the vicinity of live bottoms, which could be destroyed directly by construction activities, or smothered by resettling sediment.

On the other hand, the structure itself will provide a large area of firm substrate for various barnacles, hydroids, echinoids, algae and other hard substrate and epifaunal species. Gallaway (1980) reported that the major effect of development of the Buccaneer Gas and Oil Field in the northwestern Gulf has been to provide substrate for development of a rich and diverse biofouling or artificial reef community. Artificial reefs, such as oil platforms, also have been found to attract fish, for reasons including food, shelter, the presence of calm water or favorable currents, and the apparent attraction of fish to solid objects for orientation purposes (Stone, 1978). There has been some debate as to whether platforms and other artificial reefs merely attract and concentrate fish, or whether they actually increase the productivity or carrying capacity of the system. An increasingly accepted theory has elements of both points of view: initially, fishes are simply concentrated by recruitment from surrounding waters, but as succession progresses on the platform, a distinctive, reproducing, resident (in part) fish community evolves (Dugas et al, 1979).

Concentrations of fish in turn attract fishermen, and it is expected that booster station platforms, like the artificial reefs placed in North Carolina waters by the Division of Marine Fisheries, would become important recreational resources. Dugas et al. (1979) attribute the rise of a major offshore recreational fishery in the Gulf in the last thirty years largely to the construction of offshore drilling platforms.

Platforms also have a couple potential, minor drawbacks for fisheries. One is the loss of access to the area underneath and near the platform for commercial fishermen using trawls, dredges and long lines. Since recreational fishing pressure will probably more than make up for the lost catch, the net result will be a slight shift in available fishery resources from commercial to recreational fishermen. The other potential drawback was observed during the studies of the Buccaneer Gas and Oil Field (BGOF) off Texas. Evidence gathered suggests that in concentrating both fish and fishermen, platforms contribute to the development of very heavy fishing pressure on stocks attracted to the platform. Based on the BGOF studies, Gallaway (1980) speculated that most of the annual recruitment of red snapper in the BGOF is harvested by sport fishermen at oil platforms, and that sportfishing at platforms has played an important role in the decline of red snapper populations in the Gulf.

The presence of one or two intermediate booster station platforms will have an insignificant effect in these regards. Only if offshore structures begin to proliferate will these factors require attention.

An additional concern with offshore platforms is their potential disruption of navigation. A great deal of vessel traffic passes the North Carolina coast between the Sale 56 lease tracts and shore, and a booster station platform located in the middle of these shipping routes will create a hazard for both shipping and the pipeline. The Coast Guard's Port Access Routes study (mentioned earlier) concluded that development of the six tracts off Cape Lookout, an area where a booster platform could be located, could

interfere with a large portion of the vessel traffic in this area. On the other hand, the Navy already maintains four platforms astride these shipping routes in the offshore waters between Oregon Inlet and the Virginia line.

The coexistence of shipping and the offshore oil industry in the Gulf for years attests to the potential compatibility of the two, but certain precautions must be taken. In addition to implementing such standard measures as designation of platforms on charts and notices in the Coast Pilot and Notices to Mariners, the Coast Guard is authorized to take two more substantial steps. Under authority of the Ports and Waterways Safety Act of 1978 (33 U.S.C. §1223), the Coast Guard may designate fairways or traffic separation schemes to route traffic safely around platforms. The Coast Guard also may establish safety zones of up to 500 meters around platforms, within which vessel activity may be prohibited or controlled (33 C.F.R. §147).

All platforms require Section 10 permits from the Corps. During the course of review, all of these concerns will be considered, not only by the Corps, but by various fish and wildlife agencies (NMFS, USFWS, N.C. Division of Marine Fisheries, N.C. Wildlife Resources Commission), the Coast Guard, and others.

9.2.3 Access Roads, Service Roads, Borrow Pits and Disposal Piles

Land adjoining or near the right-of-way will be needed for a variety of minor activities during pipeline construction and operation, including temporary access roads to the construction site, permanent service roads to aboveground facilities, borrow pits for sand, gravel and other fill used in construction, and disposal piles for excess subsoil and other materials. Such facilities are common to most major construction projects, and their impacts and appropriate precautionary measures are well known. Unfortunately, the will and attention to detail needed to prevent such impacts are often lacking.

The effects of these facilities will include: temporary or permanent changes in land use, destruction of vegetation, destruction and disturbance of wildlife, short- and long-term changes in habitat, disruption of drainage, accelerated soil erosion, degradation of aesthetic and recreational resources, and noise and air pollution. Temporary causeways across streams built to facilitate construction of the pipeline crossing will produce many of the same effects as the crossing itself.

These impacts can be minimized if they receive adequate attention during planning and construction. The siting of many of these features can be quite flexible and therefore can be more sensitive to small and relatively less important features than can the pipeline itself. To the greatest extent possible, these facilities should be sited in previously disturbed areas, and maximum use made of existing roads for access and servicing.

9.3 EXISTING RIGHTS-OF-WAY AND UTILITY CORRIDORS

The sharing or paralleling of existing utility and transportation rights-of-way by pipelines will considerably reduce the impacts of pipeline construction and operation and should be encouraged. Facilities whose rights-of-way might be shared or paralleled include highways, railroads, overhead

power lines and telephone lines, and underground pipelines (gas, water, sewer), power lines, and communication cables.

Two terms commonly used in such discussions should be distinguished. Existing rights-of-way are just that: rights-of-way chosen, assembled, and used for a particular facility, usually without regard for future facilities, or at least those of other operators. Pipelines may be built within existing rights-of-way where space and safety permit, but a large diameter pipeline is more likely to be built in a right-of-way adjacent to and paralleling an existing right-of-way. The term "corridor," on the other hand, is reserved for routes that are designated or assembled with the specific intention of being used by more than one facility and operator. The entire corridor width may be assembled in fee simple or easement by a single company, or it may be designated by a public agency, with each company obtaining a right-of-way for its facility within the corridor.

The use of existing rights-of-way or corridors for pipeline routing has a number of advantages. From the public's standpoint the major one is a reduction in the amount of previously undisturbed land that will be affected by construction and operation activities. Even when existing rights-of-way are paralleled rather than shared, the existing right-of-way can be used as working and storage space, thereby reducing the amount of additional undisturbed land needed for construction. As compared with installation in a new right-of-way, use of existing rights-of-way will substantially reduce destruction or disturbance of vegetation, wildlife and wildlife habitat, previously undisturbed landforms and aquatic bottom, natural areas, aesthetic landscapes, and other environmental resources. The combined permanent right-of-way width is usually less than the sum of the widths of two single rights-of-way, thus also reducing long-term impacts on land use and environmental character, as well as concentrating such impacts in one location. Mimimizing the land area disturbed is particularly important in crossing sensitive environmental resources such as wetlands, maritime forest, and important natural areas.

The use of existing rights-of-way or corridors may provide financial savings to pipeline companies as well, through:

- common access roads,
- narrower widths of right-of-way to be bought or leased, and
- common maintenance.

Existing rights-of-way and corridors also have a number of disadvantages. The major one is the cost incurred by following a more circuitous route. Highways and railroads go from city to city, and powerlines from generating station to substation, and rarely will any of these lie along the route preferred by a new pipeline for any substantial distance. Other disadvantages of corridors include:

- the hazard or interference created by other users of the right-of-way or corridor;
- the danger of concentrating too many utilities in one location (the all-eggs-in-one-basket syndrome), with respect to natural disasters, accidents and sabotage; and
- the frequent inferiority of the space available for new utilities as the first facility along the route usually takes the best location, leaving additional facilities with progressively poorer locations.

Different types of facilities involve different considerations for use of their rights-of-way by pipelines:

Highways. Pipelines are usually located parallel to existing highway rights-of-way rather than within them. In congested urban areas, however, it may be necessary to install the pipeline within the roadway itself, and in fact, urban roadways often double as utility corridors, being the most readily available routes for gas, water, sewer, telephone and power lines. Construction within urban roadways will necessitate closing of at least part of the roadway, and at least temporary relocation of a number of existing utility lines.

The sharing or paralleling of highway rights-of-way in less developed areas offers a number of advantages over new routes. Highway construction will have minimized the clearing and grading necessary for pipeline construction, access is readily provided by the road, and in some cases the roadway may even be used as a working surface. A major disadvantage of using highway rights-of-way is the potential cost and inconvenience of pipeline relocation if the highway is widened or improved.

Railroads. The potential for use of railroad rights-of-way will depend on the characteristics of the particular line. As a general rule, rail service may not be interrupted, and any interference with train schedules or the railroad's use of the track is not permitted (Golden et al., 1980). Railroads have been reluctant to share their rights-of-way with pipelines because of the hazards presented by the lines, and have also contended that pipeline cathodic protection systems may interfere with railroad signal and communication systems through electrolysis (Elder, 1981). On the other hand, railroad rights-of-way may be as much as 100 feet wide, and since only 15-20 feet will be occupied by the railbed itself, there may be a substantial amount of room for accommodating other utilities. Since railroad lines are restricted to gentle grades, the route often requires little grading.

Powerlines. As ground conditions for powerline routes need only be sufficient for the periodic placement of towers, these rights-of-way may not be as suitable as roads and railroads for pipeline construction. Powerline rights-of-way do offer the advantage of no surface traffic to accommodate, but they have several disadvantages due to by the presence of high voltage lines. During construction, these lines create two safety hazards: 1) the danger of physical contact with the lines or other energized materials; and 2) possibly dangerous voltages induced by electric field coupling on aboveground metal objects, particularly construction equipment and the pipe itself. These effects can be readily mitigated by the careful operation of equipment and proper grounding of all metallic surfaces. Once the pipeline is buried, AC transmission lines will induce voltage and current on pipelines that may enhance corrosion, interfere with cathodic protection devices and communications equipment, and deliver potentially serious shocks to personnel at aboveground appurtenances. Eliminating or rendering harmless these induced voltages and currents has proven far more difficult, though some precautions can be taken. (Bridges and Hancock, 1981; Dabkowski and Frazier, 1981; FERC and USDOI/BLM, 1981)

Underground Lines. The major concern in sharing rights-of-way with other underground lines is the hazard to one line created by the construction,

testing, operation and repair of others. Although it is desirable to minimize right-of-way width, the savings in cost and environmental impact will be lost, if pipeline safety is compromised. There is no standard minimum separation distance. If two lines are laid simultaneously by a single operator, they may be laid in a single ditch; large diameter gas lines laid at different times, on the other hand, usually have a separation of at least 20-30 feet.

In North Carolina there are numerous examples of pipelines utilizing existing rights-of-way, particularly highways. The N.C. Department of Transportation (NCDOT) has no written policy on use of highway rights-of-way by pipelines, but there are a number of instances of such use both adjacent to the right-of-way and within the right-of-way on the road shoulder. During construction NCDOT policy requires that at least one lane be kept open to traffic, but other lanes may be used for construction work. However, utilities may not be installed within the rights-of-way of limited access, high speed highways, NCDOT's intent being to keep such highways and their shoulders free of construction and maintenance vehicles for safety reasons (Murray, 1982).

It is established federal policy to encourage the use of existing rights-of-way and the designation of corridors. FERC's regulations on gas pipeline routing (18 C.F.R §2.69) state that, "In locating proposed facilities, consideration should be given to the utilization, enlargement or extension of existing rights-of-way belonging to either applicant or others, such as pipelines, electric powerlines, highways, and railroads." The Federal Land Policy and Management Act of 1976 (P.L. 94-579, also known as the BLM Organic Act) requires that on BLM lands "the utilization of rights-of-way in common shall be required to the extent practical" and authorizes the Secretary of the Interior to designate corridors and to require utilities to locate within them (43 U.S.C. §1763).

Based on the considerations above, the following pipeline siting criteria related to existing rights-of-way and corridors are suggested:

1) Existing Rights-of-Way. Pipelines should utilize or parallel existing rights-of-way wherever feasible and wherever compatible with both safe operation of the pipeline, the safety of other facilities present, and the users of those facilities.

2) Corridors. The establishment of utility corridors by industry should be encouraged wherever practical. In connection with the state's decision-making authority, the question arises as to whether such corridors should be established for crossings of public lands, and whether the use of rights-of-way adjacent to existing ones should be required where construction requires state permits.

In general, requiring new lines to be laid adjacent to existing ones makes sense environmentally only when and where the damage created by the original lines has not been eliminated and the area fully restored at the time of the new line's construction. Using this reasoning, the permanent designation of corridors is justified where the damage caused by pipeline installation persists. In addition, corridors should be designated only where the value of the resource to be protected justifies the economic cost of the detour. Establishing an offshore corridor requiring a twenty-mile detour (at

a cost of $1 million per mile) around a 100-foot wide live bottom reef is simply not warranted. Corridor designation then becomes a matter of scale: some types of resources justify only small detours or route adjustments, and others much larger ones.

The analysis of the preceding chapters suggests that, with a few exceptions, resources valuable enough to require pipeline reroutings of several miles or more comprise only a small fraction of the total area in coastal North Carolina. Examples of such resources include primary nursery areas, wetlands, natural areas, and state parks. Rather than recommend the establishment of long corridors, then, it is more reasonable to consider designating short corridors or "windows" through such environmentally sensitive areas, or avoidance or exclusion areas. Other corridor routing studies have come to similar conclusions (Breuninger, 1981).

Furthermore, with several possible exceptions, detours of more than 5 to 10 miles around these resources are difficult to justify, and the distances between "windows" or the dimensions of avoidance areas should not be greater than this. There are three, possibly four, resources the state should consider as possible exceptions:

1) with respect to oil pipelines, all inside waters north of Cape Lookout;

2) with respect to gas pipelines, Pamlico Sound and possibly Core Sound, as productive fishing waters too valuable to permit the disturbance generated by pipeline installation over extended distances, particularly by flotation canal;

3) Core Banks as a natural area bordering on wilderness within the National Park System; and

4) major and productive reefs or reef complexes that may yet be discovered on the Carolina shelf, if trenches are to be excavated by blasting.

Avoidance areas of this magnitude should be designated early in field development planning to spare pipeline companies wasted effort on route surveys and other planning activities. Other "windows" or short corridors need not be designated ahead of time. In permitting the first pipeline route through a sensitive environmental area, however, state agency officials should consider the possibility of future pipelines and the desirability of routing them next to the first. The route should be designed accordingly, and appropriate stipulations attached to the permits or easement. The Federal Land Policy and Management Act mentioned earlier, for instance, requires that "each right-of-way or permit shall reserve to the Secretary concerned the right to grant additional rights-of-way or permits for compatible uses on or adjacent to rights-of-way granted pursuant to this Act." Official corridor designation is never really necessary, as each line may be evaluated on the merits of using either a new or existing right-of-way. Planning for other uses of the resource, however, may at some point make pipeline corridor designation desirable.

X. OVERVIEW OF SITING CONCERNS AND RECOMMENDATIONS

10.1 SUMMARY OF SITING CONCERNS

There are three general categories of environmental features or resources whose presence, from a public perspective, should be considered in siting hydrocarbon pipelines. These categories are:

1) environmental resources or resource uses sensitive to pipeline construction and operation activities;

2) features and activities that present a hazard to the integrity of a pipeline; and

3) resources or resource uses sensitive to pipeline breaks and spills.

These three topics have received varying amounts of coverage in the preceding text. The major focus of this report has been on the impacts of pipeline construction and operation on environmental resources and resource uses in the coastal zone, and on the implications of those impacts for siting pipeline rights of way. Most of the siting recommendations below are based on those findings. In addition, the various hazards to pipeline safety have been considered, primarily in the offshore and landfall environments, and these also figure prominently in the recommendations below. The sensitivity of coastal zone environments and activities to spilled oil and gas, on the other hand, have been examined at length in other publications and are only covered briefly in this report.

There is no standard method or formula for combining these three sets of considerations to produce ideal pipeline routes. The process would be difficult enough if all of the potential impacts and problems that could occur were known with certainty. Unfortunately, our understanding of natural systems is such that, given that a certain event occurs (such as pipeline construction or an oil spill), our ability to predict the resulting impacts is far from perfect. The problem is compounded by the fact that the occurrence and size of pipeline spills are highly probabilistic and cannot yet be estimated with any reasonable degree of confidence.

Thompson (1981) points out that in making tradeoffs among unlike resources during the siting of utility corridors, three different parameters must be considered for each resource and each segment of the landscape:

1) the relative importance of the resource affected;
2) the relative magnitude of the impact to that resource, which, since it cannot be accurately predicted, must be dealt with in terms of "impact risk"; and
3) the relative degree to which the impact can be mitigated.

Such an approach provides a useful framework for considering the siting implications of pipeline impacts, and this approach has been applied in the analyses of the preceding chapters.

One of the most basic and elementary conclusions to be drawn from these analyses is: In many instances, the construction methods used and the steps taken to restore an area following installation will have as much or more of an influence on the severity of impact experienced by the environmental or economic system than will the location of the pipeline route. Moreover, our knowledge and ability to restore different environments differ. Thus, while one route might be preferable given one choice of construction methods or one level of monetary commitment to impact mitigation and restoration, another

route might be better given another mix of methods and effort. The point to be emphasized is that route location cannot be considered independently of the choice of how to construct the pipeline and how to restore the right-of-way -- impacts need to be minimized within the context of all three sets of factors considered simulataneously.

With this in mind, though, it is possible to make some general siting recommendations "assuming all other factors are equal." Based on the preceding analyses of (1) resources and resource uses sensitive to pipeline construction and operation activities, and (2) features and activities that present hazards to the safe operation of a pipeline, a set of siting recommendations or criteria have been compiled by which proposed pipeline routes may be planned or evaluated. These recommendations are presented in Table 10-1. The recommendations are divided into five major groups, depending on the geographic area of application (offshore, barrier islands, estuaries, rivers and lakes, and upland), with a sixth category for recommendations applicable in two or more of these areas. It is our recommendation that pipeline routes be selected to meet as many of these criteria as possible; furthermore, it is our belief that if most of these criteria are met, the potential for significant impacts as a result of pipeline construction and operation will be substantially reduced.

Several specific conclusions can also be drawn regarding the need for designated pipeline corridors. First, the resources and activities that are sensitive to pipeline construction and operation are for the most part small and scattered; they do not cover large areas encompassing most of the coastal zone. As a result, it should be possible to thread a pipeline through these areas across almost any section of the coast with minimal impact. The designation of a few long corridors within which pipelines would be restricted therefore appears unwarranted, particularly considering the millions of dollars in additional construction costs that would be spent if circuitous routes are necessary to meet corridor requirements. Largely for this reason, but also because both offshore and onshore termini of future pipelines are not yet known, it is recommended that the state not designate long corridors for the routing of hydrocarbon pipelines.

Considering the size and distribution of pipeline-sensitive areas, a more effective and efficient strategy for protecting these areas would be the designation of exclusion or avoidance areas, within which pipelines would not be allowed, or allowed only under very specific conditions; or of "windows" through environmentally or culturally sensitive areas. Such designations could be made formally through explicit policy statements, or informally during the course of permit evaluation and review. The purposes of such designation would be several: to prevent damage to sensitive resources; to confine pipelines to environments or specific routes that have already been damaged or that recover rapidly from disturbance; or to confine pipelines to a single route through congested areas so as to least encumber the land or seabed for other uses and to more easily protect the pipelines.

It is our impression that, for the most part, acceptable windows may be found throughout the coastal zone at distances of no more that 5 to 10 miles apart. Because of the frequency of these windows and the relative ease with which a proposed route could be realigned to pass through one, it should not be necessary to designate these areas prior to early consultations with

Table 10-1. Summary of hydrocarbon pipeline siting recommendations for coastal North Carolina.

Throughout:	• avoid habitat occupied by threatened or endangered species, unless construction can be conducted when the habitat is not in use and restoration can be completed before the species returns
	• avoid productive wildlife areas, particularly during the seasons of heaviest use or where the damage will persist for several years
	• avoid outstanding natural areas recognized by the N.C. Natural Heritage Program, the National Registry of Natural Landmarks and similar programs
	• avoid State and National Parks and Seashores
	• avoid major wildlife refuges (National Wildlife Refuges and most productive Game Lands)
	• avoid visually important landscapes where the damage will persist for several years
	• existing rights-of-way should be shared or paralleled wherever compatible with pipeline safety, and maximum use made of other disturbed areas
	• avoid all sites on or nominated for the National Register of Historic Places
	• avoid areas of military activity (military bases, restricted waters, etc.), as indicated by the various services
Offshore:	• avoid artificial reefs and wrecks
	• avoid major ship anchorages, and where possible, congested port areas and approaches
	• avoid dump sites
	• where pipeline burial is necessary for safety and stability, avoid hard or live bottoms; if these must be crossed, choose the route to minimize the crossing distance and to avoid areas of high productivity (as indicated by fishing pressure, topographic relief, survey studies and other measures)
	• avoid geologically hazardous areas such as unstable sediments and active faults
Barrier Islands:	• avoid areas of large dunes and well-developed frontal dune systems in particular; route through areas where dunes are low and eroded or nonexistent
	• avoid stretches with high historic erosion rates; beaches showing seaward accretion are most preferable
	• avoid heavily used sea turtle nesting beaches, in season
	• avoid heavily developed areas and heavily used recreational areas, in season
	• avoid major tracts of maritime forest and other important natural areas
	• avoid areas prone to or with a history of overwash or inlet formation, and avoid areas in the vicinity of existing inlets
	• avoid concentrations of estuarine resources (marshland, grass beds, oyster reefs, colonial bird nesting colonies, etc.) fringing the sound side of the island
Estuaries:	• avoid coastal wetlands; if wetlands must be crossed, choose route to minimize length of crossing and/or to pass through either marsh types of lesser value or marshes that have been previously damaged
	• avoid: primary nursery grounds beds of seagrasses and other aquatic plants shellfish beds (particularly oyster reefs) areas of polluted sediments areas where extensive flotation canal work will be necessary colonial waterbird nesting sites major wintering waterfowl concentrations crossings of major sounds (Pamlico and Albemarle)

Table 10-1. (Continued)

Rivers and Lakes:	• avoid crossings of streams, rivers and lakes wherever possible • when a stream or river must be crossed, route should be as near as perpendicular to the stream course as possible and at a narrow point; under no circumstances should a pipeline be laid up or downstream within a riverbed or along its bank • factors to consider in choosing a crossing include: - expected ease of streambank restoration - fish spawning activity at and below the crossing site - other values and uses of the downstream river reach including rare and endangered species, productive game fish habitat, recreational use, aesthetic enjoyment, and water supply - presence of polluted sediments - stability of the stream channel and the depth of scour during floods - previous disturbance of the stream bed - width of valuable riparian or floodplain habitat on either side that must be crossed
Upland:	• avoid areas of potential phosphate, limestone, and cement mining activity • avoid congested urban areas

pipeline companies and their submission of route proposals. In fact, such designations need never be made formally, unless they would assist in the planning of natural resources or economic activities that would be affected by pipeline locations.

There are three possible exceptions, however--areas that are sufficiently large that, if pipelines are excluded from them, proposed routes would require major readjustments. To save pipeline companies the expense of such changes, it is recommended that these areas be designated by policy statement as exclusion or avoidance areas early in field exploration. These areas are:

1) The major portions of Pamlico and Albemarle Sounds, as extensive and valuable inland waters that can easily be bypassed by pipelines; and

2) The northern portion of Core Banks, as an extensive natural area of almost wilderness quality in public ownership.

10.2 MAP OVERVIEW

Two maps accompany this report. They provide an overview of the location of features sensitive to or hazardous to pipelines in coastal North Carolina. Features shown are those 1) that were determined during the course of this study to present significant contraints on pipeline route selection, and 2) for which reliable map data covering the entire North Carolina coastal zone were available. The features chosen and the data sets used are listed in Table 10-2.

We feel that these maps present the most complete and accurate depiction of these resources available at the scale presented. However, several caveats should be kept in mind in using the maps. First, not all of the coastal resources that either may be damaged by pipelines or may prove hazardous to their integrity are shown. Reliable map data are simply not available for some of these resources for the entire coastal zone, and it was felt that including data for only selected areas would be misleading and confusing. Among the significant resources not shown are shellfish beds (particularly oyster

Table 10-2. Features Mapped for the Pipeline Route Constraints Maps Accompanying This Report.

Natural Features	Source
Primary Nursery Areas	N.C. Division of Marine Fisheries
Coastal Marshes	Wilson (1962)
Pelican Nesting Colonies	Land Resources Information Service
Colonial Waterbird Nesting Colonies	Land Resources Information Service
Waterfowl Wintering and Breeding Areas	Land Resources Information Service
Swamps and Bottomland Forest	Wilson (1962)
Designated Wilderness	U.S. Fish and Wildlife Service
Proposed Wilderness	National Park Service, U.S. Forest Service
Outstanding Natural Areas	Land Resources Information Service
Coastline Erosion Rates	N.C. Department of Administration (1981)
Resource Uses	
Artificial Reefs	N.C. Division of Marine Fisheries
Major Anchorages	U.S. Army Corps of Engineers
Ports and Approaches	National Ocean Survey Charts
Area of Surface-Minable Phosphate	N.C. Geological Survey
Harbor Spoil Disposal Areas	U.S. Army Corps of Engineers
Military Restricted Areas	National Ocean Survey Charts
Major Military Bases	Alexandria Drafting Co. (1981)
Monitor Marine Sanctuary	National Ocean Survey Charts
National Register of Historic Places	N.C. Division of Cultural Affairs
National Park and State Park Units	Alexandria Drafting Co. (1981), Beccasio et al. (1980)
National Wildlife Refuges	Alexandria Drafting Co. (1981), Beccasio et al. (1980)

reefs), anadromous fish spawning areas, offshore hard grounds and rock outcrops, and urbanized areas. Furthermore, because of the scale of the maps, some small areas of resource types that were included are simply not large enough to appear (e.g., small primary nursery areas and patches of marsh). As a result, blank areas on the maps cannot be assumed to be free of routing constraints, but merely free of large-scale features of the resource types that were included. Second, the maps were designed to provide an index or overview of the pipeline-sensitive and hazardous features that may lie along proposed routes, and were not designed for specific route planning. Symbols used to mark resource locations are often much larger than the proportional size of the resource, and it may be possible to thread a pipeline safely through even the densest cluster of such symbols.

10.3 CONSTRUCTION AND RESTORATION STRATEGIES

Since the choice of construction methods and restoration techniques may have as much or more of an influence on the severity of pipeline impacts than the choice of a route, it was deemed important to present information in the report on how construction and restoration methods affect impact levels. This we have tried to do throughout Chapters VI-IX. The measures that can be taken tend to be specific to particular environments. By way of summary, however, most of these measures can be classified into one of several general strategies:

1) <u>Minimize the size of the area affected by construction and operation activities</u>. This can be split into two recommendations: (a) Minimize the total area affected. The amount of impact is frequently related directly to the area of land surface affected. (b) Minimize the amount of previously undisturbed area affected. Environmental impact will generally be less where the land has been disturbed previously. This is one basis for recommending that existing rights of way be shared or paralleled to the greatest extent feasible.

2) <u>Choose the least damaging construction alternative where technical and economic factors permit</u>. Directional drilling is environmentally preferable to open-cut crossings of rivers and waterways, and may be feasible at landfalls as well. Crossing hard or live bottoms offshore will be least destructive when other factors permit the line to be laid on the seafloor and not buried.

3) <u>Schedule construction and operation activities seasonally to avoid sensitive resources</u>. Many resources and activities can be completely avoided by the proper scheduling of pipeline activities. These resources include heavily used recreational beaches, sea-turtle nesting sites, and ground nesting birds within the right-of-way. Other resources, such as estuarine benthos and nekton, will experience far less impact during the season(s) of lower productivity. Scheduling can also be important to the success of restoration efforts; construction should be completed at the most propitious time of year for restoration efforts to begin.

4) <u>Restore the disturbed area as rapidly and completely as possible</u>. This is particularly important at shoreline areas to minimize erosion and the introduction of pollutants into the water body. Where use of the environment

(by man or other organisms) is seasonal, every attempt should be made to complete restoration before the next season of heavy use.

5) Consider ways to make creative, positive use of the pipeline and its by-products. Pipelines need not have solely negative impacts on the surrounding environment, and consideration should be given to ways in which the environment may be enhanced by pipelines and associated activities. These include the functioning of pipelines and booster stations as artifical reefs, the use of dredge spoil for island vegetation management, and the increase in habitat diversity and wildlife productivity that accompanies cutting of rights-of-way through dense pine forest.

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APPENDIXES

Appendix A. Table of Acronyms Used in the Text

AEC	Area of Environmental Concern
AIBS	American Institute of Biological Sciences
ANSI	American National Standards Institute
API	American Petroleum Institute
ASME	American Society of Mechanical Engineers
BLM	Bureau of Land Management
CAMA	N.C. Coastal Area Management Act
CERC	Coastal Engineering Research Center
C.F.R.	Code of Federal Regulations
CG	Coast Guard
CRC	N.C. Coastal Resources Commission
DEM	N.C. Division of Environmental Management
DLR	N.C. Division of Land Resources
DMRP	Dredged Material Research Program
DOD	U.S. Department of Defense
DOT, USDOT	U.S. Department of Transportation
EIS	Environmental Impact Statement
EPA, USEPA	U.S. Environmental Protection Agency
FERC	Federal Energy Regulatory Commission
FPC	Federal Power Commission
F.R.	Federal Register
ICA	Institute for Conservation Archaeology
LEO	Littoral Environment Observations
LWCF	Land and Water Conservation Fund
NASA	National Aeronautics and Space Administration
N.C.A.C.	North Carolina Administrative Code
NCDOT	N.C. Department of Transportation
N.C.G.S.	North Carolina General Statute
NERBC	New England River Basins Commission
NGSDC	National Geophysical and Solar-Terrestrial Data Center
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NOS	National Ocean Survey
NPDES	National Pollutant Discharge and Elimination System
NPS	National Park Service
NRC	National Research Council
NTSB	National Transportation Safety Board
NWR	National Wildlife Refuge
OCM	N.C. Office of Coastal Management
OCS	Outer Continental Shelf
OCZM	U.S. Office of Coastal Zone Management
SAI	Science Applications, Inc.
SCS	Soil Conservation Service
SHPO	State Historic Preservation Officer
SSMO	Summary of Synoptic Meteorological Observations
U.S.C.	United States Code
USDOC	U.S. Department of Commerce
USDOI	U.S. Department of Interior
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
VIMS	Virginia Institute of Marine Science
WRC, NCWRC	N.C. Wildlife Resources Commission

Appendix B. Scientific Names of Plant Common Names Mentioned in Text

Common Name	Scientific Name
American holly	Ilex opaca
Beech	Fagus grandifolia
Black gum	Nyssa sylvatica
Black needlerush	Juncus roemerianus
Bulrush	Scirpus spp.
Camphorweed	Pluchea purpurascens
Cattail	Typha spp.
Cordgrass, Big	Spartina cynosuroides
, Saltmeadow	S. patens
, Smooth	S. alterniflora
Dwarf huckleberry	Gaylussacia dumosa
Gallberry	Ilex glabra and I. coriacea
Glasswort	Salicornia spp.
Oak, Black Jack	Quercus marilandica
, Blue-jack	Q. incana
, Laurel	Q. laurifolia
, Live	Q. virginiana
, Scrubby post	Q. margaretta
, Southern red	Q. falcata
, Turkey	Q. laevis
, Water	Q. nigra
, White	Q. alba
, Willow	Q. phellos
Pine, Loblolly	Pinus taeda
, Longleaf	P. palustris
, Pond	P. serotina
Red bay	Persea borbonia
Red cedar	Juniperus virginiana
Red maple	Acer rubrum
Saltgrass	Distichlis spicata
Sawgrass	Cladium jamaicense
Sea lavender	Limonium spp.
Sea myrtle	Baccharis halimifolia
Sea ox-eye	Borrichia frutescens
Sweet bay	Magnolia virginiana
Sweet gum	Liquidambar styraciflua
Tulip poplar	Liriodendron tulipifera
Wax myrtle	Myrica cerifera
Yaupon	Ilex vomitoria

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